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INNOVATIONS IN INSURANCE – FROM TRADITIONAL TO MODERN MARKET



UNIVERZITET U BEOGRADU
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Foreword

The monograph “Innovations in Insurance – From Traditional to Modern Market” explores the dynamic transformation of the insurance industry in an era marked by economic, institutional, environmental and technological change. As global risks evolve and new challenges emerge, from climate-related disasters to rapid digitalisation, the insurance sector must rethink traditional models and embrace innovation as a strategic imperative. The monograph reflects a multidisciplinary approach to understanding how the insurance industry is adapting to a shifting risk landscape, regulatory demands, and customer expectations. The authors address both longstanding and emerging issues, ranging from investment constraints and financial resilience to the integration of artificial intelligence, green finance, and climate risk mitigation into insurance practice.

The first part of the monograph examines the role of insurance innovation in managing environmental risks and supporting sustainable development. The contributions explore a variety of mechanisms through which insurers can play a more active role in environmental protection and risk mitigation. Topics include the development and implementation of environmental liability insurance, the influence of air pollution on demand for life and health insurance, and the potential of catastrophe (CAT) bonds to provide financial protection against climate-related disasters. The authors also analyse how green financing instruments can be leveraged in times of geopolitical uncertainty, and how innovations in agricultural insurance can support sustainability.

The second part of the monograph focuses on the economic and institutional environment that shapes innovation in the insurance sector. Authors examine the macroeconomic foundations and policy frameworks that enable or constrain the development of a modern insurance market, with special attention given to the context of Serbia. Topics include innovative approaches to measuring development achievements in a comparative European context, the impact of economic uncertainty and monetary policy on financial services, and the evolving role of pension and deposit guarantee schemes. By analysing the structural conditions under which insurers operate, this section sheds light on the systemic factors that determine the pace and direction of innovation in the sector.

The third part of the monograph is dedicated to the performance of insurance companies, the risks they face, and the investment strategies they employ in a

rapidly changing economic environment. This section explores how insurance companies across the region are responding to evolving market conditions, regulatory requirements, and the need to strengthen financial stability. Case studies from Bosnia and Herzegovina and Montenegro provide a comparative view of innovation readiness and accounting practices in the insurance industry. Other chapters focus on insurers' investment behaviour, including the balance between regulatory constraints and market opportunities, and the role of insurance in managing exchange rate risk. Furthermore, analytical models for assessing the financial stability of insurers are presented, and the implications of collective bargaining in the financial services sector are discussed.

The fourth part of the monograph explores the transformative impact of digital technologies on the insurance industry. As technological innovation accelerates, insurers are increasingly turning to advanced tools such as machine learning, artificial intelligence (AI), expert systems, and digital analytics to improve decision-making, personalise customer experience, and enhance operational efficiency. Contributions examine the challenges and opportunities of applying AI and machine learning in risk assessment, fraud detection, customer segmentation, and predictive modelling. The role of web metrics and digital marketing in the modernisation of insurance services is also addressed, as well as the development of corporate governance systems supported by intelligent technologies. By showcasing practical applications and discussing the strategic implications of digital transformation, this part of the monograph demonstrates how technology is reshaping the traditional insurance model and driving the emergence of a data-driven and customer-centric industry.

We express our sincere gratitude to the authors for their valuable contributions and to the reviewers for their thoughtful comments, which have greatly enhanced the quality of this monograph. We hope that the insights offered here will inform academic research, professional practice, and policy decisions in the ever-evolving field of insurance.

EDITORS

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PART I

**INSURANCE INNOVATION
IN RESPONSE TO
ENVIRONMENTAL RISKS AND
SUSTAINABLE DEVELOPMENT**

Chapter 1.

ENVIRONMENTAL INSURANCE AS A RESPONSE TO INCREASING ENVIRONMENTAL RISKS: CHALLENGES AND PERSPECTIVES

The environment is considered a public good. Natural resources, including air, water, land, flora, and fauna, are accessible to all, and their degradation negatively impacts society as a whole. As natural resources become increasingly scarce, environmental protection has never been more important than today.¹ However, environmental risks are a relatively new area of societal concern. Only in the past half-century has society started to prioritise them. Therefore, practical methods for managing these risks are still in their infancy.² This chapter examines environmental insurance as one of the most effective contemporary instruments for preventing and managing environmental risks.

An inevitable consequence of economic development is the degradation of the ecological environment and the increasing frequency of environmental pollution. Persistent environmental challenges exert significant pressure on the sustainability of economic growth. Industrial expansion and rapid urbanisation drive economic progress but also lead to resource depletion, pollution, and ecological degradation. These issues threaten public health, biodiversity, and the stability of key economic sectors. Sustainable development requires striking a balance between economic activities and environmental protection to ensure that growth does not come at the expense of future generations. Governments are responding to these challenges by introducing stricter environmental regulations and encouraging the adoption of green technologies, while economic entities are increasingly embracing sustainable business practices and implementing responsible investment policies. Environmental insurance plays a crucial role in this process by encouraging companies to internalise environmental risks, comply with sustainability standards, and mitigate financial losses from pollution incidents.

¹ OECD (2003). Environmental Risks and Insurance No. 6: A comparative Analysis of the Role of Insurance in the Management of Environment-Related Risks. *Policy Issues in Insurance*, Paris: OECD, p. 22.

² Freeman, P. K., & Kunreuther, H. (2012). *Managing environmental risk through insurance*. Springer Science & Business Media, p. 4.

Environmental insurance is a type of insurance coverage that protects against risks threatening the environment, including air, water, and soil pollution, loss of biodiversity, destruction of natural resources, and other damages resulting from accidents or negligent behaviour by companies or individuals. This type of insurance focuses on protecting the environment and minimising the consequences of ecological disasters. The primary function of environmental insurance is to provide financial protection against the realisation of environmental risks. These risks refer to hazards that may endanger the natural environment, human health, or the quality of essential resources. They can be natural, such as floods, earthquakes, or droughts, or anthropogenic, meaning caused by human activities, such as pollution, deforestation, improper waste management, or the emission of harmful gases. Identifying environmental risks is crucial for the implementation of environmental insurance, as it enables the anticipation of potential damages that may result from specific activities.

In response to the global challenge of sustainable environmental development, the European Union has recognised the importance of environmental protection and established standards and regulations that its member states must observe. These efforts have created an institutional framework for managing environmental risks and their consequences through the implementation of environmental insurance. This chapter aims to explore the potential for introducing environmental insurance in Serbia based on a comparative analysis of international experiences, with particular attention given to the necessary conditions for its effective application.

1. GROWING ENVIRONMENTAL POLLUTION RISKS

Since the publication of "Silent Spring" by Rachel Carson in 1962, which highlighted the detrimental effects of human development on the environment, global awareness of ecological issues has increased significantly. This seminal work sparked the modern environmental movement and led to the first United Nations Conference on the Environment in 1972. Despite ongoing assessments of environmental damage caused by human activities since then, ecological degradation has continued both sporadically and systematically to this day.³

Climate change is no longer a looming threat—it is a present reality intensifying the frequency and severity of environmental disasters. As floods, droughts, wildfires, and biodiversity collapse increasingly affect lives and economies worldwide, new tools are urgently needed to govern environmental pollution

³ Rahmatiar, Y. (2018). The role of environmental insurance as the prevention effort of environmental pollution. *Journal of Arts and Humanities*, 7(5), p. 46.

risks and ensure equitable resilience. Traditional responses have proven insufficient, often reactive rather than preventive. Insurance, traditionally associated with post-disaster compensation, is now evolving to play a more proactive role in managing environmental risks and supporting climate adaptation.

This text explores environmental insurance as a forward-looking mechanism that addresses both natural and anthropogenic environmental risks. Building on critical insights into the colonial nature of extractive capitalism and the need to achieve resilience in interconnected economic systems, this section outlines how environmental insurance can transition from niche application to a structural component of climate governance, especially under conditions of ecological debt and systemic inequality.

According to the IPCC the global economy is currently experiencing profound ecological disruption, already facing 1.5°C of global warming⁴. Scientific forecasts predict a trajectory toward 3.5°C warming if current policies persist⁵. With the historical shift out of ecological reserves in the 1960s, the ongoing exploitation of nature is unsustainable. Planetary boundaries have been breached, and yet, extractivist logic continues to dominate economic policy, particularly in high-income nations.

This trajectory is not an accident, but the result of capitalism's colonial orientation. Post-growth scholars argue that the current system's requirement for perpetual expansion externalises socio-environmental costs onto vulnerable populations. Climate change, biodiversity loss, deforestation, and water contamination are all exacerbated by development models that are rooted in the Global North's extraction of resources from the Global South. These extractivist policies continue under the guise of "green transitions", where supposedly sustainable technologies still demand heavy environmental tolls.

A contemporary example is lithium extraction, often framed as essential to decarbonisation and the electrification of transportation. However, the ecological, social, and cultural risks are especially pronounced when this extraction occurs

⁴ Tešić, N., Kočović De Santo, M., & Radosavljević, K. (2023). New insurance directions as a response for climate change. In: *Challenges and insurance market's responses to the economic crisis*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 191-213.

⁵ Intergovernmental Panel on Climate Change (2021). Climate change 2021, The physical science basis. *Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC (Retrieved May 1, 2023 from <https://www.ipcc.ch/report/ar6/wg1/>)

in fertile, rich cultural and biodiversity areas with access to non-renewable supplies of clean water. As shown in the case of Serbia, lithium extraction proposals threaten rich agricultural land and aquifers, because the process often disregards local community members who oppose projects which violate environmental and social justice principles. Such and similar projects produce not only physical pollution but also ecological debt—deferred environmental destruction with intergenerational consequences.

Climate change-induced droughts, floods, and erratic weather patterns severely threaten food security, which is the reason to bring the comparisons between ongoing economic and agricultural activities and their effects versus lithium extraction in the Jadar valley. Insurance mechanisms are being introduced, but without structural changes to production models or environmental safeguards, these remain reactive rather than preventative.

Joan Martínez-Alier's foundational concepts of the *environmentalism of the poor*⁶, *sacrifice zones*, and *ecological debt*⁷ offer critical insights for understanding the ecological conflict dynamics surrounding the Jadar Valley lithium project in Serbia. These frameworks help understand the role of Serbia as part of Europe's periphery—a sacrifice zone increasingly subjected to extractivist projects in the name of the "green transition" and the "greater good." Such narratives, while invoking climate urgency, often obscure the neo-colonial patterns underpinning extractive development.

Discourses on climate change articulated by hegemonic political and corporate actors frequently perform a subtle expropriation of local autonomy. Communities resisting imposed megaprojects are routinely constructed as irrational, misinformed, or manipulated, thus justifying continued exploitation under the banner of progress. This rhetorical framing delegitimises local knowledge systems while privileging technocratic and corporate visions of sustainability.

A clear structural divide persists in today's global order—between the Global North and South, between centre and periphery—manifesting in the unequal distribution of resources, political power, and environmental burdens. Peripheral regions, like western Serbia and the Jadar valley, are systematically selected as

⁶ Martínez-Alier, J. (2002). *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*. Edward Elgar Publishing.

⁷ Martínez-Alier, J., Temper, L., Del Bene, D., & Scheidel, A. (2020). Is there a global environmental justice movement? The Global Environmental Justice Atlas (EJAtlas): Ecological Distribution Conflicts as Forces for Sustainability. *Journal of Peasant Studies*, 47(5), pp. 999-1024.

destinations for the externalisation of ecological costs associated with the industrial production of the Global North. This process represents an embedded form of neo-colonial logic, whereby natural wealth is extracted and environmental damage localised, while economic benefits flow elsewhere⁸.

Recent political narratives deployed by European officials, corporate representatives, and supportive media outlets reveal a troubling inversion of knowledge. Legitimate concerns raised by residents of the Jadar Valley are often dismissed as products of misinformation or foreign (specifically Russian) interference, while other alternative visions of development are subordinated to techno-economic and corporate framings.

The lithium extraction project is thus discursively framed as a precondition for modern development, but where, and for whom? At the same time, rural life and agriculture are characterised as outdated or backwards alternatives. This framing reinforces the implicit global role assigned to peripheral nations: to service the needs of the industrialised core, often at their own ecological and social expense. As expressed by EU officials, Serbia is offered the "opportunity" to become part of the lithium value chain. This becomes clearer if we add that the wealthiest 1% produce over 15% of global emissions, while the poorest 50% are responsible for only 7%. Yet, environmental degradation—polluted rivers, toxic air, and degraded soils—disproportionately impacts the poorest communities⁹. Despite an increase in global disaster-related losses, averaging \$170 billion annually, only 45% were insured in 2022.¹⁰ In many developing countries, less than 10% of losses are covered by insurance, revealing not only unequal exposure to climate risks but also unequal access to recovery mechanisms.

These risks extend to the rise of diffuse and chronic pollution forms: soil contamination from industrial waste, air pollution from extractive, energetic and

⁸ Kočović De Santo, M. (2024). Životna sredina za sirotinju: Srbija kao zona žrtvovanja. *Danas*, print edition, Saturday–Sunday, July 27–28, 2024; Kočović De Santo, M. (2024). Da li je vredno i za koga da Srbija bude nova kolonija?, *Danas*, August 3, 2024, <https://www.danas.rs/dijalog/licni-stavovi/da-li-je-vredno-i-za-koga-da-srbija-bude-nova-kolonija/>

⁹ Oxfam (2020). Confronting Carbon inequality - Putting climate justice at the heart of the COVID-19 recovery. *Oxfam Media Briefing* (retrieved May 1, 2023 from <https://oxfamlibrary.openrepository.com/bitstream/handle/10546/621052/mb-confronting-carbon-inequality-210920-en.pdf?sequence=1&isAllowed=y>)

¹⁰ Cvijanović, D., Radosavljević, K., & Kočović De Santo, M. (2024). Agricultural insurance in response to climate challenge. In: *Transformation of the insurance market: responses to new challenges*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 165-189.

more related projects, and freshwater degradation from overuse and runoff. The environmental insurance is now emerging as a possible buffer to these risks. However, it remains in its infancy and struggles with core challenges: a lack of adequate legal frameworks, insufficient data for environmental damage valuation, and institutional inefficiencies.

Environmental insurance can potentially serve as both a compensatory and preventative tool. Ultimately, managing rising environmental risks means acknowledging the deep structural forces at play: the historical overconsumption of natural resources by the Global North, the continued exploitation of the Global South under green capitalist paradigms, and the urgent need for ecological reparations and solidarity-based insurance frameworks. Insurance is one tool, but without fundamental shifts in how we define growth, development, and risk, it will remain a bandage over deeper wounds.

2. REGULATORY FRAMEWORK OF THE EU IN THE FIELD OF ENVIRONMENTAL PROTECTION

In the practice of European Union (EU) member states, differing views on environmental insurance persisted for a long time. However, the scope of liability insurance for environmental pollution was established with the adoption of the EU Environmental Liability Directive concerning the prevention and remediation of environmental damage in 2004 (Directive 2004/35/EC)¹¹. This directive assigns responsibility for the costs of preventing and remedying environmental damage and sets requirements for financial guarantees to ensure environmental liability.

The aim of Directive 2004/35/EC is to prevent and remediate environmental damage, as well as to establish liability for such damage based on the "polluter pays" principle. This principle implies that the party responsible for causing the damage through a hazardous activity, one from which they derive economic benefit, must bear the costs of the damage.¹² Article 3 of this Directive stipulates that its provisions must be applied to: a) environmental damage resulting from any of the economic activities listed in the Annex to the Directive,¹³ as well as in

¹¹ Directive 2004/35/EC of the European Parliament and of the Council on environmental liability with regard to the prevention and remedying of environmental damage, *Official Journal of the European Union*, L 143/56

¹² Labudović Stanković, J. (2012). Osiguranje od odgovornosti za štete prouzrokovane životnoj sredini. *Teme*, XXXVI(3), p. 1263.

¹³ The list of activities includes the operation of industrial installations covered by Directive 96/61/EC on integrated pollution prevention and control, which has since

cases where there is an imminent threat of such damage; and b) damage to protected species and natural habitats resulting from any other economic activity, including cases where there is an imminent threat of such damage, regardless of whether the operator acted negligently or without fault. The concept of environmental liability has evolved significantly from the understanding that liability for large-scale environmental disasters falls under the category of "comprehensive general liability" to the recognition of environmental insurance as a distinct type of liability insurance for environmental damage. This type of insurance defines the insurer's liability in the event of claims for compensation resulting from environmental harm, regardless of its scale.¹⁴

The European Union has established a comprehensive legal framework governing environmental protection, with several key directives forming the foundation for the implementation of environmental insurance, including:

1. *Environmental Liability Directive – ELD (2004/35/EC)* – assigns environmental liability to those responsible for causing environmental damage, establishing clear guidelines for prevention and remediation;
2. *Water Framework Directive (2000/60/EC)* – regulates the protection of water resources from pollution and, in the context of insurance, enables coverage for damages caused by water contamination;
3. *Industrial Emissions Directive – IED (2010/75/EU)* – sets guidelines for the prevention and control of industrial pollutant emissions, which may also be covered by environmental insurance in the event of an accident;
4. *Thematic Strategy for Soil Protection* – sets out basic guidelines for protecting soil from degradation and pollution, providing a legal basis for insurance coverage of remediation costs for land contaminated by industrial activities or chemical substances;
5. *Seveso III Directive (2012/18/EU)* – establishes strict requirements for the prevention and control of industrial accidents involving hazardous substances, requiring operators to implement measures to limit environmental consequences. In the context of environmental insurance, this directive stimulates demand for insurance policies that cover remediation costs and liability in the event of major chemical incidents.

been repealed and replaced by Directive 2010/75/EU on industrial emissions (IED), as well as waste management, operation of landfills and incineration plants, discharge of hazardous substances into surface or groundwater, water abstraction and impoundment, production, storage, processing and transport of dangerous substances, operation of installations emitting pollutants into the air, use and release of genetically modified microorganisms, and transboundary shipment of waste.

¹⁴ Моткин, Г. А. (2010). *Экологическое страхование: Итоги и перспективы*, Москва: НИЦ Экопроект, р. 20.

The directives mentioned above define environmental risks as hazards that may potentially endanger the environment as a result of human activities. Environmental risks include:

1. *Pollution* – Pollution of air, water, and soil represents one of the most significant environmental risks. Activities such as industrial production, transportation, agriculture, and improper waste disposal can lead to serious environmental problems. These activities may result in the emission of harmful gases that pollute the atmosphere. Industrial wastewater, oil spills, chemical leaks, and improper storage or disposal of waste can contaminate soil, groundwater, rivers, lakes, and seas, causing severe damage to the environment and ecosystems.
2. *Soil erosion* – Agricultural activities and deforestation can lead to soil erosion, which negatively affects soil quality, biodiversity, and food production.
3. *Climate change* – Changes in climatic conditions caused by human activities, such as the emission of CO₂ and other greenhouse gases, can lead to extreme weather events, including floods, droughts, and heat waves.¹⁵
4. *Biodiversity loss* – The excessive exploitation of natural resources and the destruction of habitats lead to a decline in biodiversity, which can threaten ecosystems and the living conditions of many species.

The European Union directives establish strict standards that ensure accountability for environmental damage, thereby reducing risks to nature and communities. Understanding these regulations and securing adequate environmental insurance lays the foundation for a sustainable future.

3. THE ROLE OF ENVIRONMENTAL INSURANCE IN ENSURING SUSTAINABLE DEVELOPMENT

Environmental pollution liability insurance, hereafter referred to as "environmental insurance," emerged in industrialised countries in response to the environmental challenges brought about by rapid industrialisation. Since the mid-1960s, the introduction of increasingly stringent environmental regulations has made it difficult for some enterprises to bear the high costs associated with major

¹⁵ See more in: Kočović, J. (2022). Contemporary challenges and perspectives of insurance market development. In: *Development of modern insurance market – constraints and possibilities*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 8-10; and Kočović, J., Tešić, N., & Koprivica, M. (2023). Izazovi osiguranja u eri klimatskih promena, *Proceedings of the 11th Scientific Conference EkonBiz*, Mitrašević, M. (ed.), Bijeljina: University of East Sarajevo, Faculty of Business Economics, pp. 73-75.

pollution incidents. Consequently, the growing need for financial protection led to the development of environmental insurance,¹⁶ as a mechanism for balancing environmental responsibility with economic interests.

Environmental insurance is a specific type of insurance that protects against financial losses arising from the realisation of environmental risks. The essence of environmental insurance lies in compensating for damage to the environment that results from economic activities. This may include air, water, and soil pollution, as well as harm to human and animal health. Environmental insurance ensures the coverage of costs associated with the remediation of environmental incidents, including the cleanup of contaminated areas, compensation to affected parties, and the restoration of ecosystems.

Environmental insurance is a significant factor that can contribute to sustainable development. In order to achieve sustainability, economic development and environmental protection must be aligned. Sustainable development entails meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. This approach involves the integration of environmental, economic, and social dimensions of development, with a particular emphasis on minimising the negative impact on nature. Sustainable development can be achieved through the proactive management of environmental risks and the implementation of preventive measures aimed at reducing environmental harm, raising awareness about the importance of environmental protection and the role of environmental insurance in risk reduction, and fostering cooperation among government institutions, insurance companies, and other economic actors exposed to environmental risks.

Typically, environmental insurance applies to businesses, industrial complexes, transportation companies, and other entities that may cause environmental damage. It may also be held by landowners and property operators whose activities could impact the environment. For example, facilities that use hazardous chemicals or nuclear power plants are expected to carry environmental insurance due to the potential for soil contamination, air pollution, and harmful effects on human health.

Environmental insurance fulfils three main functions. First, it protects individual companies from bankruptcy by spreading the risks and costs of environmental pollution across a group of polluters. Second, it ensures that victims of

¹⁶ Ren, G., & Shang, J. (2010). The Conditions of China's Environmental Liability Insurance System. In: *4th International Conference on Bioinformatics and Biomedical Engineering*, IEEE, p. 1.

environmental damage can receive compensation, even if the company responsible for the disaster goes bankrupt. Lastly, environmental insurance helps reduce environmental risks by incentivising polluters to invest in risk reduction and prevention measures.¹⁷

By transferring environmental liability risks to insurers, environmental insurance alleviates financial pressure on enterprises, helping them mitigate potential cash flow disruptions caused by litigation claims, pollution compensation, and remediation costs. In turn, by reducing banks' credit risk, environmental insurance provides polluting enterprises with better access to bank loans.¹⁸ Additionally, purchasing environmental insurance sends a positive signal of corporate social responsibility to investors, thereby reducing the cost of capital.¹⁹

Beyond financial relief, environmental insurance plays a key role in fostering green innovation. Its risk-sharing mechanism allows enterprises to allocate more resources to R&D without fear of unexpected environmental costs. Insurers can adjust pricing to incentivise and reward policyholders for investing in environmental innovation to mitigate potential risks. To lower their premiums, insured companies are motivated to comply with environmental standards, invest in safer technologies, and implement other preventive measures, thereby mitigating environmental risk. Consequently, environmental insurance plays a crucial role in maintaining ecological balance and protecting the natural environment. Additionally, to prevent moral hazard and minimise insured losses, insurance companies perform an external supervisory function through pre-underwriting assessments and continuous post-underwriting monitoring.²⁰ By acting as third-party regulators alongside government regulations, insurance companies help create a dual regulatory framework that enhances environmental awareness and promotes sustainable business practices.²¹

¹⁷ Freeman, P. K., & Kunreuther, H. (2012). *Managing environmental risk through insurance*. Springer Science & Business Media

¹⁸ Lyu, C., Xie, Z., & Li, Z. (2022). Market supervision, innovation offsets and energy efficiency: Evidence from environmental pollution liability insurance in China. *Energy Policy*, 171, p. 2.

¹⁹ Ning, J., Yuan, Z., Shi, F., & Yin, S. (2023). Environmental pollution liability insurance and green innovation of enterprises: Incentive tools or self-interest means? *Frontiers in Environmental Science*, 11, p. 3.

²⁰ Косариков, А. Н., Иванов А. В., Шевченко, Ж. А. (2003). *Экологическое страхование и оценка рисков*, Нижний Новгород, p. 57.

²¹ Wen, H.-x., Cui, T., Wu, X.-q., & Nie, P. (2024). Environmental insurance and green productivity: A firm-level evidence from China. *Journal of Cleaner Production*, 435(2024), p. 3.

Several studies have provided evidence on the relationship between environmental insurance and corporate performance, green innovation, energy efficiency and pollution reduction. Wu et al. (2022) claim that environmental insurance positively affects corporate environmental performance by alleviating financing constraints.²² Wen et al. (2024) find that environmental insurance promotes a firm's green total factor productivity. Ning et al. (2023) show that environmental insurance facilitates green innovation of enterprises by relaxing financing constraints and reducing agency costs.²³ A positive relationship has also been found between environmental insurance and energy efficiency.²⁴ Zhu et al. (2023) argue that environmental insurance encourages enterprises to cut emissions by reducing coal and oil consumption while expanding investments in emission control technologies.²⁵ Yin et al. (2011) find that mandating environmental insurance contributed to reducing toxic releases from underground storage tanks in the United States.²⁶

4. IMPLEMENTATION OF ENVIRONMENTAL INSURANCE: EVIDENCE FROM DEVELOPED AND DEVELOPING COUNTRIES

Environmental insurance was first introduced in the 1970s in developed countries with mature insurance markets, such as the United States, Germany, France, and the United Kingdom. In the 21st century, developing countries face a complex Prisoner's Dilemma when balancing economic growth and environmental protection.²⁷ In pursuit of rapid development, they tend to prioritise industrial growth and infrastructure at the expense of environmental protection. However,

²² Wu, W., Zhang, P., Zhu, D., Jiang, X., & Jakovljevic, M. (2022). Environmental pollution liability insurance of health risk and corporate environmental performance: evidence from China. *Frontiers in Public Health*, 10, p. 8.

²³ Ning, J., Yuan, Z., Shi, F., & Yin, S. (2023). Environmental pollution liability insurance and green innovation of enterprises: Incentive tools or self-interest means? *Frontiers in Environmental Science*, 11, p. 9.

²⁴ Lyu, C., Xie, Z., & Li, Z. (2022). Market supervision, innovation offsets and energy efficiency: Evidence from environmental pollution liability insurance in China. *Energy Policy*, 171, p. 4.

²⁵ Zhu, D., Chen, K., Sun, C., & Lyu, C. (2023). Does environmental pollution liability insurance promote environmental performance? Firm-level evidence from quasi-natural experiment in China. *Energy Economics*, 118, p. 9.

²⁶ Yin, H., Pfaff, A., & Kunreuther, H. (2011). Can environmental insurance succeed where other strategies fail? The case of underground storage tanks. *Risk Analysis: An International Journal*, 31(1), pp. 15-16.

²⁷ Zhu et al. (2023), op. cit., p. 1.

this short-term strategy can result in long-term ecological degradation. The introduction and development of environmental insurance can help developing countries pursue more sustainable growth while preserving natural resources for future generations.

Two primary forms of environmental insurance can be identified: voluntary and compulsory. Voluntary environmental insurance allows companies to make their own decision about purchasing coverage. In contrast, compulsory environmental insurance mandates specific industries to obtain coverage.²⁸ Experience from both developed and developing countries shows that compulsory environmental insurance tends to perform better than voluntary environmental insurance.²⁹ The need for introducing compulsory environmental insurance arises from constraints on both the demand and supply sides of the insurance market.

On the one hand, industrial enterprises often tend to underestimate the environmental risks arising from their operations, which makes them reluctant to purchase environmental liability insurance.³⁰ In developing countries in particular, polluting companies frequently have limited awareness of their environmental responsibilities, as governments have traditionally borne the costs of environmental damage. Weak enforcement and deficiencies in environmental compensation laws further reduce the incentive for companies to seek coverage. Due to the limited number of insured entities, it is not possible to establish a sufficiently large risk pool for effective risk dispersion.

On the other hand, the unique characteristics of environmental pollution risks make them particularly challenging to insure. These risks, especially gradual pollution, are often hard to detect and may not become evident for years, making causal links with actual loss unclear.³¹ Environmental losses also tend to be large—and in some cases, catastrophic—often exceeding the financial capacity of the insurance sector. Moreover, the amount of loss is typically difficult to

²⁸ Feng, Y., Mol, A. P., Lu, Y., He, G., & van Koppen, C. K. (2014). Environmental pollution liability insurance in China: compulsory or voluntary? *Journal of Cleaner Production*, 70, p. 212.

²⁹ Ibid, p. 217.

³⁰ OECD (2012). *Liability for environmental damage in Eastern Europe, Caucasus and Central Asia (EECCA): Implementation of good international practices*, Paris: OECD, p. 27.

³¹ Rahmatiar, Y. (2018). The role of environmental insurance as the prevention effort of environmental pollution. *Journal of Arts and Humanities*, 7(5), p. 47.

estimate at a specific point in time.³² Gradual pollution, characterized by latency and long-term effects, complicates insurance coverage because it is hard to determine when the pollution began and how long it lasted. Insurance limits may become inadequate due to inflation given the long-tail nature of environmental risks. Synergetic pollution, where multiple sources contribute to environmental harm, further complicates risk identification and underwriting. Additionally, the insurability of environmental risks is closely tied to the regulatory framework. Uncertainty or a lack of clear regulations can limit the insurability of risk, while well-defined environmental rules can foster the development of an effective pollution insurance market. Moral hazard is also a significant concern, as high-risk polluters may perceive insurance coverage as a "license to pollute."³³ In developing countries in particular, the insurance sector often faces limited financial resources and lacks the necessary expertise to model environmental risks and establish adequate insurance premium rates.

These constraints in the insurance market result in a limited number of companies willing to purchase coverage and a lack of attractive and affordable products offered by insurers.³⁴ Consequently, voluntary schemes struggle with low demand, slow market development, and minimal competition,³⁵ which hinders the potential of environmental insurance to contribute to sustainable development. In contrast, compulsory environmental insurance fosters larger risk pools, greater competition and lower premiums.

EU Member States, pursuant to Article 14 of the Environmental Liability Directive (ELD), are required to encourage the development of financial security instruments and related markets to enable operators to meet their environmental liability obligations. These financial security instruments may take various forms, including insurance policies, bank guarantees, bonds, or own reserves. However, Member States are not legally obliged to make such financial security mandatory.

³² Anderson, D. R. (1998). Development of environmental liability risk management and insurance in the United States: lessons and opportunities. *Risk Management and Insurance Review*, 2(1), p. 2.

³³ OECD (2003), op. cit., p. 41.

³⁴ See more in: Kočović, J., Koprivica, M., & Jović, Ž. (2021). Sustainable development of insurance in crisis conditions. In: *Contemporary Challenges and Sustainability of the Insurance Industry*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, p. 18.

³⁵ Ren, G., & Shang, J. (2010). The conditions of China's environmental liability insurance system. In: *4th International Conference on Bioinformatics and Biomedical Engineering*, IEEE, p. 3.

Figure 1. Financial security for ELD liabilities in the EU



Source: European Court of Auditors (2021), *op. cit.*, p. 28.

The system of mandatory financial security exists in only a few EU Member States, including the Czech Republic, Ireland, Italy, Poland, Portugal, Slovakia, and Spain (Figure 1).³⁶ Most Member States have opted for voluntary mechanisms. While environmental liability insurance is the main form of voluntary financial security, take-up remains low. Research findings indicate that insurance policies covering ELD liabilities are not widely available across the EU, and in some Member States, they do not exist at all. Additionally, availability does not always match demand, as some countries report high availability but low demand (Figure 2). However, in countries where financial security is mandatory, this has helped develop the environmental insurance market.³⁷ As a result, the European Commission is considering a mandatory EU-wide financial security scheme that includes insurance.³⁸ Introducing a mandatory insurance mechanism is considered "one of the most controversial and crucial focal points in the development process of the Environmental Liability Directive".³⁹

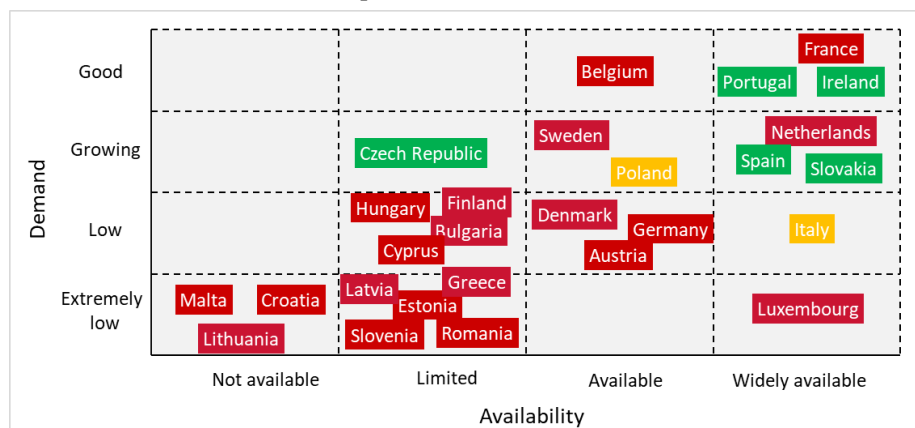
³⁶ European Court of Auditors (2021). *The Polluter Pays Principle: Inconsistent application across EU environmental policies and actions*. Luxembourg: ECA, p. 27.

³⁷ Fogleman, V. (2020). *Improving financial security in the context of the Environmental Liability Directive*. Brussels: European Commission, pp. 204-206.

³⁸ Skinner, N. (ed.) (2011). *A Guide to Environmental Liability in Europe*. StrategicRISK, p. 1, <https://www.strategic-risk-global.com/download?ac=21944>

³⁹ Cassotta, S. (2012). *Environmental Damage and Liability Problems in a Multilevel Context. The Case of the Environmental Liability Directive*. Kluwer Law International, p. 198.

Figure 2. Availability and demand for stand-alone environmental insurance policies in the EU



Source: Prepared based on Fogleman (2020), *op. cit.*, pp. 200-206.

It is important to note that Many EU Member States have imposed mandatory financial security requirements for environmental liabilities beyond EU law. For example, insurance or equivalent instruments are required for waste management permit holders (Croatia, Cyprus, Hungary), waste transporters (Germany, Greece), exploration permit holders (Finland), home oil tank owners (Denmark), and land transactions (Belgium).

An increasing number of developing countries are introducing mandatory environmental liability insurance. In recent years, such measures have been adopted in Argentina, China, Kazakhstan, and Turkmenistan (Table 1). In Kazakhstan, the Law on Mandatory Environmental Insurance requires legal and natural persons engaged in environmentally hazardous activities to hold environmental insurance. These entities are not permitted to operate without an environmental insurance policy issued by an insurer licensed to provide this type of coverage. The insurance contract must specify the sum insured (coverage limit), which represents the insurer's maximum liability per insured event, with the minimum sum insured prescribed by law. The insurance premium is negotiated between the policyholder and the insurer, with a lower and upper limit of the premium rate defined, which is applied to the agreed sum insured. The minimum contract duration is 12 months. The law also sets a deadline within which the insurer must pay compensation following the occurrence of an insured event. The list of environmentally hazardous activities is determined by the competent state authority.⁴⁰

⁴⁰ <https://adilet.zan.kz/rus/docs/Z050000093>

Table 1. Key features of mandatory environmental insurance systems in selected developing countries

	Argentina	China	Kazakhstan	Turkmenistan
Year introduced	2002 – Legal requirement introduced; operational enforcement started in 2007–2008.	Pilot programs from 2008; guidelines issued in 2013; draft national regulation in 2017 (not yet enforced)	2005 – Law adopted; system effective from 2006.	2013 – Mandatory environmental insurance in force since March 1 for all applicable entities.
Covered industries	Activities with medium or high environmental complexity, based on a government risk classification system.	Defined list of high-pollution sectors (e.g. chemicals, oil/gas, hazardous waste), including firms with major incidents since 2005.	List of hazardous activities defined by decree; includes heavy industry and high-risk operations.	Government-issued list of environmentally hazardous activities (e.g. mining, chemicals, oil/gas).
Insurer	Licensed private insurance companies	Licensed private insurance companies	Licensed private insurance companies	State insurance company
Minimum insured amount	Yes – set by regulation, based on the environmental risk level of the activity.	No fixed minimum; sum insured is determined by contract.	Yes – set by law: 5,000× MCI (individuals), 65,000× MCI (companies), where the MCI is a monetary index set by the budget law each year.	Yes – set by law: 100 times base value for injury, 4,000 times base value for property/environmental damage, where base value is a government-set reference amount.

Premium rates	Risk-based and negotiated; no fixed tariffs; insurers assess risk individually.	Risk-based within regulatory framework; insurers set base rates adjusted for risk factors; regulator approval required.	Negotiated but legally bounded; premium must stay within 0.76%–2.65% of the insured sum.	Fixed tariff rates set by law according to category of hazardous activity.
Covered risks	Environmental damage and remediation costs. Third-party injury/property damage is not covered. Gradual pollution is implicitly covered.	Environmental damage, third-party injury/property damage, and cleanup costs. Legal expenses may be included. Gradual pollution is generally covered.	Environmental damage and third-party losses from accidental pollution events. Only sudden incidents are insured. Gradual pollution is not covered.	Environmental damage and third-party injury/property damage from accidental pollution events. Only sudden incidents are insured. Gradual pollution is not covered.
Sanctions for non-compliance	Denial or revocation of permits, fines, and suspension of operations until insurance is obtained.	Fines, suspension of permits or approvals, restriction of access to environmental subsidies, and temporary shutdown until coverage is obtained.	Fines and temporary suspension of facility operations until insurance is provided.	Fines and suspension of operations until insurance is provided.

Source: Prepared based on Molina & Chona (2009); www.argentina.gob.ar; www.eldial.com; www.marval.com; Rödl & Partner (2017); www.chinalawvision.com; <https://english.mee.gov.cn>; <https://practiceguides.chambers.com>; <https://theeurasia.kz>; <https://vic.kz>; Jafarova (2013); <https://turkmeninform.com>; <https://insurance.gov.tm>; www.global-regulation.com.

Global annual premiums for environmental pollution liability insurance are estimated at less than USD 3.5 billion,⁴¹ representing less than 0.1% of total global non-life insurance premiums.⁴² More than half of this amount is attributed to the U.S. market alone. According to the World Economic Forum's Global Risk Report 2024, five of the ten most severe global risks projected over the next decade are environmental in nature: extreme weather events (ranked 1st), critical changes to Earth systems (2nd), biodiversity loss (3rd), natural resource shortages (4th), and pollution (10th).⁴³ Given this context, it is evident that there is substantial potential for the development of the environmental liability insurance market at a global level.

5. CHALLENGES IN THE IMPLEMENTATION OF ENVIRONMENTAL INSURANCE IN SERBIA

For the widespread implementation of environmental insurance in Serbia, several significant objective challenges must be overcome to establish an effective system for environmental protection and maintain ecological balance. These challenges are not merely administrative or legislative in nature but also relate to a broader range of factors, including financial capacities, damage assessment methodologies, data availability, and the quality of institutional support. Some of the most prominent challenges include:

- a) inefficiency of the state in remediating environmental damage;
- b) lack of sufficient financial resources within companies to remedy the effects of environmental incidents (accidents);
- c) lack of a standardised methodology for determining the monetary value of environmental damage;
- d) lack of transparent statistics on natural resources and the state of the environment;
- e) lack of an adequate institutional and legal framework necessary for the implementation of environmental insurance;
- f) limited financial capacity of insurers to cover damages caused to the environment.

⁴¹ United Nations Environment Programme Finance Initiative (2022). *New risks, new opportunities: Harnessing environmental pollution liability insurance for a sustainable economy*. Geneva: UNEPFI, p. 8.

⁴² Swiss Re (2023). World insurance: stirred, and not shaken. *Sigma*, 3(2023), p. 38.

⁴³ World Economic Forum (2024). *The Global Risk Report 2024*, 19th Edition, Geneva: WEF, p. 8.

a) Inefficiency of the state in remediating environmental damage

One of the main challenges in the field of environmental protection is the inefficiency of state institutions in responding promptly and effectively to environmental disasters and their adverse consequences resulting from human activity. There is often a problem with the issuance of permits for projects that pose significant environmental risks, as well as a lack of coordination between different national and local authorities. There is also a lack of efficiency in addressing the consequences of environmental incidents, which often leads to further environmental degradation—providing an additional argument for the establishment and implementation of environmental insurance. By introducing mandatory environmental insurance through a public-private partnership model, the state could, in cooperation with insurers, compensate for the shortfall in funds needed for environmental remediation. This would enable more accurate allocation of resources and faster intervention in urgent environmental situations, thereby laying the foundation for a more systematic approach to environmental protection.

b) Lack of sufficient financial resources within companies to remedy the effects of environmental incidents (accidents)

Companies that cause environmental incidents often lack sufficient funds to remediate the damage or compensate affected communities and victims. Due to the complexity of assessing environmental disasters from both financial and operational aspects, many companies are unable to cover the costs of remediation and compensation. This represents a serious problem for environmental sustainability, as it often leads to the long-term neglect of corporate responsibility towards the environment. Mandatory environmental insurance could address this issue, as companies would be legally required to pay insurance premiums, thereby ensuring that insurers compensate the affected parties and reducing the risk of financial incapacity to remedy the environmental consequences of their activities.

c) Lack of a standardised methodology for determining the monetary value of environmental damage

Due to the variety of damage types—such as long-term impacts on biodiversity, water or soil contamination, and harm to human health—it is challenging to calculate accurately the actual costs of remediation and compensation. Different approaches and methodologies exist depending on the type of environmental incident. However, there is still no adequate methodology that would allow for consistent and precise valuation of damage, which is essential for determining insurance premiums, where the expected value of loss is the most dominant component. The implementation of environmental insurance could contribute to the development and standardisation of these methodologies, as insurance

companies would be motivated to design methods enabling accurate damage assessments in order to appropriately determine premiums and compensation amounts. This would allow them to develop a range of products covering specific environmental risks and, through mandatory environmental insurance that encompasses a broad base of policyholders, ensure access to coverage for all environmental polluters—both legal entities and individuals. Without a mandatory system, many of them would not meet the conditions for inclusion.

d) Lack of transparent statistics on natural resources and the state of the environment

There is currently a significant issue related to the lack of transparency and readily available data on the state of the environment and natural resources. Environmental information is often not collected in real time or is inadequately analysed, which hinders timely decision-making regarding environmental protection. Moreover, data on resources—such as water and energy—are not sufficiently integrated into broader environmental strategies. To implement environmental insurance, it is necessary to establish a national database on environmental resources and their current status, including records of environmental damage. Such a national environmental statistics system would enable more accurate monitoring of environmental risks and faster responses in the event of their materialisation or the occurrence of environmental damage.

e) Lack of an adequate institutional and legal framework necessary for the implementation of environmental insurance

It is necessary to establish institutional preconditions for the introduction of mandatory environmental insurance by creating a specific type of liability insurance for environmental damage. This represents the appropriate approach to implementing such insurance. Introducing mandatory environmental insurance for companies whose activities may seriously endanger the environment—air, soil, and water—requires the imposition of strict conditions regarding environmental protection measures. Legislation should mandate compulsory insurance for specific high-risk industries, such as the oil industry, mining, chemical production, and agriculture. By adopting appropriate regulations, companies are both obligated and encouraged to invest in environmental insurance.

Liability for environmental pollution in Serbia is regulated by the Law on Environmental Protection. According to the "polluter pays" principle, the polluter is responsible for the damage caused to the environment and bears the full cost of measures to prevent and reduce pollution, including the costs of damage assessment and remediation. The Law on Environmental Protection also prescribes mandatory insurance for polluters whose facilities or activities pose a

high risk to human health and the environment, covering liability for damage caused to third parties. Any person who suffers damage has the right to compensation, which can be claimed directly from the polluter or the polluter's insurer or financial guarantor if such entities exist. The Republic of Serbia reserves the right to claim compensation in cases where no other party is entitled to it.⁴⁴ However, the law does not specify which economic activities are subject to the requirement for mandatory liability insurance. As a result, there is a challenge in determining the entities to which the insurance obligation applies.⁴⁵ Additional legislative shortcomings concern the absence of essential elements in the mandatory insurance contract, which partly explains why this type of insurance is not available as a standalone product on the domestic insurance market. The Environmental Protection Act does not specify the risks covered by the insurance, prescribe a minimum sum insured, or define a mechanism for monitoring the implementation of mandatory insurance contracts.⁴⁶ In Serbia, environmental pollution liability insurance can only be arranged as supplementary coverage within general liability insurance. In the absence of precise legal regulations, the definition of the insured risk in environmental liability insurance is left to the autonomous regulation of insurance companies.⁴⁷ According to the General Terms and Conditions for Liability Insurance, if specifically agreed upon and subject to the payment of an additional premium, the policy includes coverage for property damage resulting from environmental pollution, including damage to land and water. This insurance coverage applies only if the pollution resulted from a sudden and unforeseen event that deviates from the regular course of business. Consequently, damages to the environment that arise gradually and as a result of continuous exposure are not covered, although such damages occur more frequently in practice than sudden ones.⁴⁸

Beyond establishing a clear legal framework, it is essential to develop supporting policies that foster the growth of environmental insurance. The state may provide subsidies or tax relief to companies that invest in environmental risk prevention

⁴⁴ Law on Environmental Protection, *Official Gazette of the Republic of Serbia*, No. 135/2004, 36/2009, 36/2009 – other law, 72/2009 – other law, 43/2011 - Constitutional Court decision, 14/2016, 76/2018 i 95/2018 – other law, articles 102-107.

⁴⁵ Molnar, D., & Koprivica, M. (2024). Osiguranje kao instrument upravljanja rizicima u rudarstvu – primer Srbije. In: *Ekonomski rast i ekonomska stabilnost*, Krstić, G., & Randelović, S. (eds.), Belgrade: Serbian Scientific Society of Economists, Faculty of Economics and Business, University of Belgrade, p. 150.

⁴⁶ Labudović Stanković (2012), op. cit., p. 1273.

⁴⁷ Molnar & Koprivica (2024), op. cit., p. 150.

⁴⁸ Šulejić, P. (2000). Zagađivanje životne sredine i osiguranje. *Pravni život*, 40(11), p. 473.

or choose to purchase environmental insurance. Moreover, raising awareness about the importance of environmental insurance is essential. Insurance companies and business operators should be trained in identifying environmental risks and implementing suitable insurance solutions.

f) Limited financial capacity of insurers to cover damages caused to the environment

Given that environmental pollution-related damages can be extremely large, the question arises as to whether insurers in the domestic market have sufficient capacity to provide coverage at an affordable premium. Pooling resources through the establishment of insurance pools can enable a more balanced distribution of risk, increased capacity to cover large environmental losses, and the maintenance of affordable premiums for policyholders. In this context, the example of France is particularly relevant. As early as 1989, France established a pollution liability insurance pool that brought together all insurers and reinsurers operating in the country to share risk jointly. The French experience demonstrates that broader participation by insurance companies, combined with strong public awareness of environmental risks, contributes to a higher uptake of pollution liability insurance at relatively lower premium levels.⁴⁹

**Toward a New Architecture for Environmental Insurance -
Introducing mandatory environmental insurance**

The introduction of mandatory environmental insurance constitutes a critical instrument for addressing the previously identified structural and regulatory challenges. Although prevailing perspectives often advocate for its application only in the context of large-scale environmental catastrophes, we contend that mandatory coverage should extend to all activities posing environmental risks, regardless of their frequency or intensity, insofar as they may endanger air, soil, or water quality. Such a policy would entail the imposition of stringent environmental protection requirements on companies engaged in environmentally hazardous operations. While the complete elimination of environmental risks and their consequences remains unattainable, mandatory environmental insurance provides the most robust and systematic mechanism for mitigating risks and promoting long-term environmental sustainability.

Institutional foundations must be established for the development of environmental insurance by introducing and designating it as a distinct category

⁴⁹ Zvezdov, I. M. (2020). The EU Legal and Regulatory Framework for Measuring Damage Risks to the Biodiversity of the Marine Environment. *Environmental Policy: An Economic Perspective*, p. 131.

of liability insurance for environmental damage. Environmental insurance would facilitate improved planning and remediation of ecological harm, as well as enable a more efficient allocation of responsibility among enterprises, insurers, and the state. Moreover, it would create a mechanism that incentivises companies to adopt preventive measures aimed at minimizing the likelihood of environmental incidents while also ensuring financial protection in the event of a disaster. The establishment of such insurance would require legal compliance with environmental standards and directives of the European Union.

Unlike traditional insurance models, which provide compensation after damage has occurred, environmental insurance adopts a proactive approach to managing environmental risks. It offers incentives for reducing the frequency and severity of such risks, thereby minimising potential losses and aligning with the principles of sustainable development. Environmental insurance encompasses the design and implementation of insurance products in a way that promotes sustainability. In light of the aforementioned challenges, the development of an effective environmental insurance system must rest on a sound institutional framework, firmly grounded in environmental protection principles and the broader agenda of sustainable development.

What could be additional elements of mandatory environmental insurance model for Jadar project?

Context: Sharp Findings from the Jadar Project

Misrepresentation of Jadar project Impact: Jadar project was publicly framed as a small, “invisible” mine. In reality, it spans over 2,000 hectares, involves daily use of 4 to 5 tons of underground explosives, and would generate up to 72 million tons of toxic tailings in 22.000 days of planed exploitation. Insurance must cover not only post-damage costs but the full environmental liability — land loss, contamination, cultural and biodiversity destruction, as well as social and medical risks.

Power Imbalance: Corporate voices dominate public discourse (80% of speaking time), while local and domestic expert voices are marginalised and re-contextualised. Insurance must factor in not just physical damages but the erosion of epistemic justice — protecting communal rights to self-representation in risk evaluation.

Delegitimisation of Resistance: Opposition is portrayed as irrational or foreign-influenced, while corporate interests are framed equally as national progress and interests. Environmental insurance must account for social impacts, including the

suppression of alternative development paths (agriculture, tourism, animal stocks etc.).

Neocolonial Extraction Patterns: While EU countries experiment with less-destructive lithium extraction, Serbia is offered outdated or high-risk methods, which shall be experimentally tested in the Jadar valley. Environmental insurance regimes must be decolonial, recognising asymmetries in risk exposure, technological access, social and environmental justice. The project frames extractivism as the only green transition path to the future, erasing alternatives. Environmental insurance must challenge this by embedding local temporality and value systems into how risk is defined and covered.

As environmental risks escalate due to extractivist development models, new governance tools are urgently needed. The Jadar Valley lithium project exemplifies the cascading ecological and social risks related to green transition. Life Cycle Assessment (LCA), traditionally used for environmental accounting, can now be repurposed as a predictive tool for environmental insurance, shifting from post-damage compensation to proactive risk prevention.

To translate these conceptual demands into operational mechanisms, environmental insurance must evolve into a proactive and systemic risk governance tool. This involves linking premium structures to measurable environmental performance, aligning financial instruments with long-term ecological resilience, and embedding equity principles into insurance design. The following recommendations outline the necessary elements of such a redefined model, tailored to the specific context of the Jadar Valley.

Expand Insurance to Prevention, and tie premiums to ecological behaviour - reward restoration, penalise degradation and negative externalities. This assumes public-private insurance pools, as well as internationalisation of risks through reinsurance. Blend of state and market funds - to insure high-risk, underregulated zones like the Jadar Valley.

Protect the life in Jadar - smallholder farmers and the ecosystem by linking environmental insurance with food security, land and population health.

Institutional Reform - Mandate environmental insurance, standardise the impact metrics via LCA method and software, and enforce transparency.

Democratise Access - Develop community microinsurance schemes that centre the needs of those most affected but least protected.

Life Cycle Assessment (LCA) as a Foundation for Environmental Insurance:

The Jadar LCA spans the full project lifecycle (40 years active, 100 years post-closure), offering metrics for long-term liability. It identifies critical risk vectors — especially water and waste management, which emerge in the most vulnerable system. LCA can serve in environmental insurance as:

- *Risk-based Premiums:* Water usage (150,000 liters/ton LCE) and contamination indicators (arsenic, boron) can be monetized as insurance risks.
- *Performance-Linked Incentives:* LCA scenarios (e.g., closed-loop systems) show drastic reductions in harm, justifying lower insurance costs for mitigation.
- *Uncertainty as Risk:* Unknowns in waste management behavior and emission factors can be insured against through adaptive, higher-premium policies.

LCA and environmental insurance are not just technical tools — they are political instruments. When wielded by inclusive coalitions, they can expose the hidden costs of extractivism, redistribute environmental risk, and protect both ecosystems and the communities that steward them. Furthermore, the environmental insurance premium can be designed to internalise the key *negative externalities* and *systemic risks* associated with the Jadar lithium mining project. The following impacts can be directly translated into quantifiable liabilities and thus form the basis for calculating the insurance premium.

Directly translatable risks for environmental insurance premiums:⁵⁰

1. Water resource depletion and contamination are significant concerns, with water depletion reaching 150,000 m³ per ton of LCE, which implies a premium charge per unit of water depletion, especially in a high-stress hydrological basin. Arsenic, boron, and sulfate pollution in wastewater create

⁵⁰ The data and categories in the text derive from multiple research sources on lithium mining and its impacts, starting from SANU monographs, RT corporative available and expert reports. Numerical values come from Life Cycle Assessment (LCA) studies that quantify the ecological footprint of Lithium Carbonate Equivalent (LCE), from extraction to final processing. Technical parameters are generated by industry reports documenting water consumption, waste generation, and pollutant emissions. Specific metrics like CTUh (comparative toxicity units for humans) and CTUe (ecotoxicity) come from standardised models such as USEtox, which enables comparative assessment of potential risks. Ecological assessments, carrying capacity analyses, and medical studies contribute to understanding health and ecosystem consequences. This comprehensive dataset serves as the foundation for calculating adequate insurance premiums that reflect the potential financial liabilities associated with the environmental risks of lithium mining.

additional risks, suggesting a risk-adjusted surcharge based on toxicity thresholds, especially for arsenic exceeding 0.01 mg/L (WHO guideline). Uncertainty in treatment efficacy also factors in, where higher uncertainty equals higher risk surcharge, especially for boron, which is difficult to remove.

2. Human and ecosystem toxicity present further challenges, with human toxicity potential ranging from 0.08–0.12 CTUh and freshwater ecotoxicity between 8,500–12,000 CTUe. This toxicity translates to premium implications based on projected health burden (DALYs, hospital visits, etc.) and biodiversity loss costs.
3. Air emissions contribute significantly to environmental impact, with global warming potential of 18–22 t CO₂-eq per ton of LCE, as well as SO_x, NO_x, and PM emissions causing acidification and respiratory health impacts. These can be priced using carbon market values, acidification health burden models, and PM_{2.5}-related morbidity data.
4. Land use change and irreversible transformation, involving land transformation of 250–300 m² per ton of LCE, create premium implications related to irrecoverable soil fertility loss, biodiversity offset costs, and long-term productivity loss of fertile agricultural land.
5. Tailings and waste management risks are considerable, with processing tailings of 18–20 tons per ton of LCE and wastewater sludge of 2–3 tons per ton of LCE, leading to premium considerations based on potential leakage, acid mine drainage (AMD), and post-closure remediation needs.
6. Post-closure liability includes a 100-year monitoring period within system boundaries, suggesting an annualised premium to cover perpetual risks from leaching, structural failures, and water table contamination.
7. Socio-cultural and agricultural disruption impacts existing rural livelihoods and food systems, with premium implications including compensation funds for agricultural losses, displacement, or social unrest (using shadow pricing or local economic dependency metrics).

Monte Carlo Simulation Outputs (e.g., 95% CI for CTUh and CTUe) can be used to set risk buffers or premium caps. Co-product allocation (Li vs. B) must be accounted for when allocating impact responsibility—critical if insurance applies only to the lithium fraction. Process modifications (closed-loop water, dry-stack tailings, advanced arsenic removal) reduce insurance costs, which can be used to incentivise cleaner practices via premium discounts. A mandatory environmental insurance scheme for cases similar to the Jadar project should integrate technical risk metrics, socio-environmental accountability, and long-term liability through a lifecycle-based premium structure, ensuring not only post-damage compensation but also proactive risk governance and environmental justice.

Chapter 2.

THE IMPACT OF AIR POLLUTION ON DEMAND FOR LIFE AND HEALTH INSURANCE

Air pollution has become a severe cause of some serious illnesses. The costs of medical care substantially increase for individuals exposed to high levels of air pollution. Air pollution also affects decision-making, as documented in some experimental research. With enormous air pollution, people have become more risk-averse and have increased their demand for life and health insurance. Theoretical and empirical arguments show that demand for life insurance is non-linear, meaning demand increases when air pollution reaches a certain threshold considered dangerous for health. Below this level of pollution, demand for life insurance might fall when air pollution increases. Demand for health insurance also exhibits a non-monotonic pattern similar to life insurance. In addition, there is a heterogeneous impact of air pollution on different individuals based on their income level, education, gender, marital status, the number of children, and the geographic location of their household. Risk perception plays an important role in insurance purchase decisions, and the impact of advertising and the behavior of friends and relatives is an important factor for air pollution risk perception. Empirical studies based on the micro-data show that the impact of air pollution is stronger on the demand for health than on the demand for life insurance.

1. HEALTHCARE COSTS OF AIR POLLUTION

One of the significant environmental and public health problems today is air pollution. Air pollution affects millions of people worldwide. Pollution is recognised as the most important environmental cause of multiple mental and physical diseases and premature deaths. The higher mortality is caused by primary air pollutants, heavy metals, organic pollutants, and several morbidity impacts (including chronic effects such as bronchitis, IQ reduction, cancer or acute effects such as cardiac and respiratory hospital admissions). In addition, pollution significantly contributes to the loss of biodiversity and reduces ecosystems' resilience and capacity to act as carbon sinks. The principal sources of pollution in 2020 were road transport, energy consumption, manufacturing, the extractive industry, agriculture, waste, and energy supply.

According to the European Environment Agency (EEA), air pollution is Europe's single most significant environmental health risk and a major cause of various diseases and premature death. The latest estimates from the EEA indicate that

fine particulate matter (PMI_{2.5}) remains the most significant contributor to health risks.⁵¹ The EEA also estimates that, in 2020, approximately 238,000 premature deaths were attributable to PMI_{2.5} in the 27 EU Member States. This accounts for 6% of annual mortality and half of the deaths in the first year of the COVID-19 pandemic. According to Fuller et al. (2022), air pollution is one of the leading causes of mortality, with exposure to indoor and outdoor air pollution associated with approximately 6.7 million premature deaths in 2019.⁵²

The impact of large PMI_{2.5} concentration in China on long-term healthcare costs (LTC) was estimated by Liu and Wan (2024)⁵³. They show that a higher concentration of PMI_{2.5} raises the likelihood that older persons need long-term care by 6.4%. On the other hand, higher pollution reduces the time spent in LTC by 0.54 years due to older persons' higher mortality rates. The first effect overweighs the second one and the total costs of LTC increase with higher air pollution. Furthermore, higher PMI_{2.5} concentration reduces a person's healthy life by 1.51 years and life expectancy by slightly more than 2 years.

According to the Awe et al. (2022), approximately 6.45 million people died from PMI_{2.5} air pollution in 2019, including ambient (outdoor) and household sources. This makes PMI_{2.5} exposure the fifth-largest health risk factor contributing to global deaths, following high blood pressure, dietary risks, tobacco smoking, and diabetes among various risk factors (Figure 1). Nearly two-thirds of these deaths (approximately 4.14 million) were attributed to ambient air pollution, while almost one-third (around 2.31 million) were linked to household air pollution. Notably, 95 percent of fatalities from PMI_{2.5} exposure occurred in low- and middle-income countries.

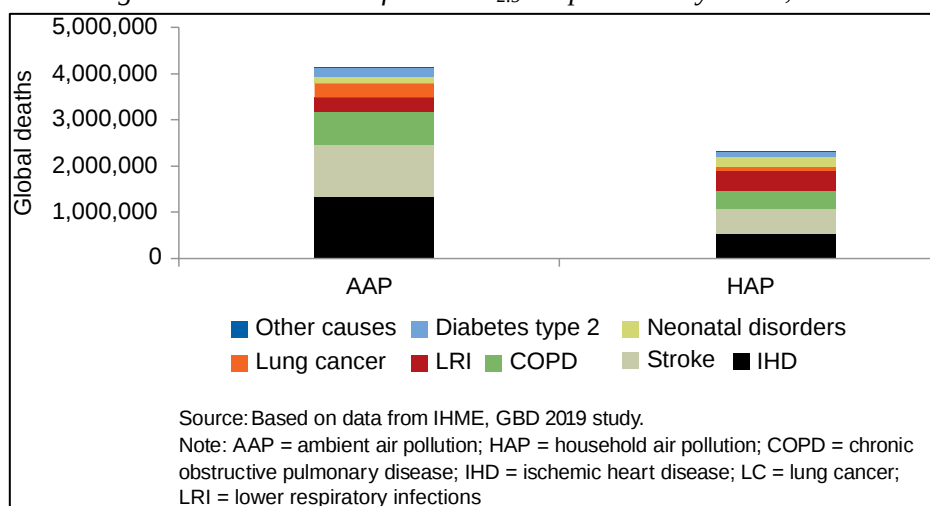
Table 1 presents the three countries (and two in one region) with the highest death rates from PMI_{2.5} air pollution in each region. The countries with the highest death rates are located in East Asia and the Pacific, Europe and Central Asia, South Asia, and Sub-Saharan Africa, with rates ranging from 106 to 202 deaths per 100,000 people. There are 32 countries with death rates exceeding 100 per 100,000 people; thirty-one are in the four regions above, while one is located in Latin America and the Caribbean.

⁵¹ <https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health>

⁵² Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., et al. (2022). Pollution and Health: A Progress Update. *Lancet Planet Health*, 6(6), 535-547.

⁵³ Liu, Z., & Wan, C. (2024). Air Pollution and the Burden of Long-term Care: Evidence from China. *Health Economics*, 33(6), pp. 1241-1265.

Figure 1. Global deaths from $PMI_{2.5}$ air pollution by cause, 2019



Source: Awe, Y. A., Larsen, B. K., & Sanchez-Triana, E. (2022). *The Global Health Cost of PM 2.5 Air Pollution: A Case for Action Beyond 2021*. Washington, DC: World Bank Group.

Table 1. Number of deaths from $PMI_{2.5}$ exposure per 100,000 people, by country in 2019

REGION	COUNTRY	DEATH RATE	REGION	COUNTRY	DEATH RATE
EAP	Korea, Dem. People's Rep.	202	NA	United States	15
	Myanmar	134		Canada	10
	China	126	SA	Nepal	130
ECA	Bulgaria	157		India	114
	North Macedonia	153	SSA	Bangladesh	106
	Bosnia and Herzegovina	145		Central African Republic	149
LAC	Haiti	113		Somalia	139
	Trinidad and Tobago	64		Chad	132
	Guyana	60			
MNA	Egypt, Arab Rep.	91			
	Morocco	80			
	Syria	72			

Note: EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and Caribbean; MNA = Middle East and North Africa; NA = North America; SA = South Asia; SSA = Sub-Saharan Africa.

Source: Awe et al. (2022), op. cit.

The adverse health effects of air pollution also have significant economic consequences. The health impacts involve substantial costs related to treating and managing illnesses caused by air pollution and indirect expenses resulting from lower productivity due to reduced working days. In 2019, the World Bank

estimated that the overall cost of air pollution on health and well-being amounted to approximately USD 8.1 trillion, representing 6.1% of global GDP.

About 85% of the total global costs associated with health damages from air pollution in 2019 were due to premature mortality, while 15% were related to morbidity. The cost of morbidity as a share of the total cost of health damages varies by country, ranging between 4% and 33%. The costs of $PMI_{2.5}$ air pollution were equivalent to 8.9% of GDP (adjusted for purchasing power parity) in low- and middle-income countries, compared to 3% in high-income countries.

Table 2 presents the three countries (and for one region, two countries) in each region with the highest welfare costs of $PMI_{2.5}$ air pollution as a percentage of GDP. The countries with the highest costs are located in Eastern Europe and Central Asia (ECA), followed by the East Asia and Pacific (EAP) region and South Asia (SA). There are 17 countries where the welfare cost of $PMI_{2.5}$ exceeds 10% of GDP, with 15 of these countries in the ECA and EAP regions and two in SA. The high costs in many ECA countries can largely be attributed to their elevated baseline death rates.

Table 2. Annual cost of health damages from $PMI_{2.5}$ by country as a % of GDP in 2019

REGION	COUNTRY	COST	REGION	COUNTRY	COST
EAP	China	12.9%	NA	United States	1.7%
	Papua New Guinea	12.0%		Canada	1.2%
	Myanmar	11.4%	SA	India	10.6%
ECA	Serbia	18.9%		Nepal	10.2%
	Bulgaria	16.3%		Pakistan	8.9%
	North Macedonia	15.9%	SSA	Burkina Faso	9.1%
LAC	Barbados	8.8%		Mali	9.1%
	Haiti	8.1%		Central African Republic	8.7%
	Trinidad and Tobago	7.8%			
MNA	Egypt, Arab Rep.	8.6%			
	Morocco	7.3%			
	Tunisia	6.5%			

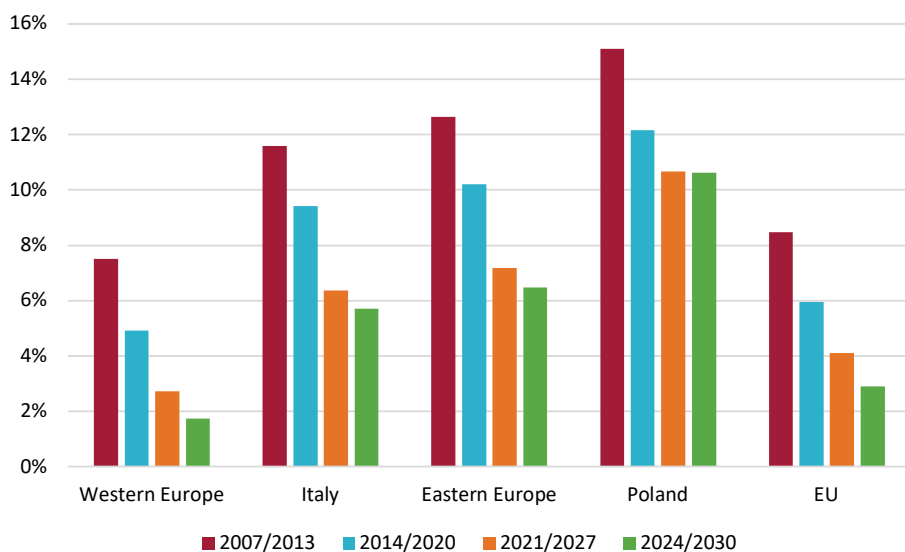
Note: EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and Caribbean; MNA = Middle East and North Africa, NA = North America; SA = South Asia; SSA = Sub-Saharan Africa.

Source: Awe et al. (2022), op. cit.

According to Mejino-López and Oliu-Barton (2024), the annual cost of air pollution in the EU from 2014 to 2021 is estimated at 770 billion EUR, or 6% of GDP. They represent less than 1% of GDP in Sweden, Finland, Estonia, and Lithuania but more than 5% in Bulgaria (6%), Italy (6%), Czechia, Croatia, Hungary (7%), Greece (8%), and Poland (10%) (Figure 1).⁵⁴

⁵⁴ Mejino-López, J., & Oliu-Barton, M. (2024). How Much Does Europe Pay for Clean Air? *Working Paper*, No. 15/2024, Bruegel.

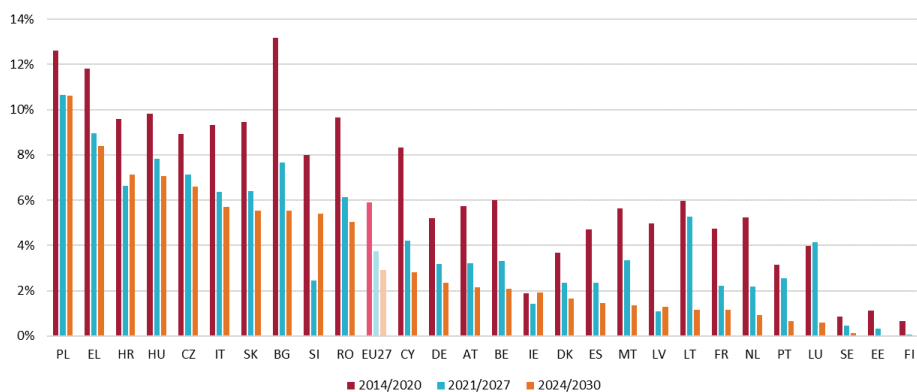
Figure 2. The costs of air pollution (% of the region's GDP over the period)



Source: Mejino-López and Oliu-Barton (2024).

Air pollution costs are disproportionately high in Eastern Europe and Italy, where losses will remain above 6% of GDP until 2030 (Figure 2). The EU's 10% most polluted regions bear 25% of the mortality burden attributed to air pollution.

Figure 3. The costs of air pollution for EU member states (% of GDP)



Source: Mejino-López and Oliu-Barton (2024).

Considering only the health and environmental costs of industrial air pollution in Europe from 2012 to 2021, the estimated external costs of industrial air emissions

ranged between 2.7 trillion EUR and 4.3 trillion EUR. This averages between 268 billion EUR and 428 billion EUR per year, as shown in Table 3.

Table 3. External costs from industrial air pollution by pollutant group (EU-27, million EUR)

Pollutant group	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	TOTAL
Main air pollutants (NH ₃ , NO _x , PM ₁₀ , SO ₂ , NMVOCs) VOLY	119,042	104,531	98,362	95,345	82,197	80,721	76,608	63,255	54,277	59,728	834,066
Main air pollutants (NH ₃ , NO _x , PM ₁₀ , SO ₂ , NMVOCs) VSL	329,152	291,050	274,609	277,302	237,010	238,591	226,419	186,285	173,111	193,056	2,426,585
Greenhouse gases (CO ₂ , CH ₄ , N ₂ O)	193,641	187,188	183,596	181,747	180,129	180,852	174,949	157,898	137,567	150,657	1,728,224
Heavy metals (As, Cd, Cr VI, Hg, Ni, Pb)	13,803	13,055	13,179	11,553	14,041	14,493	13,395	10,140	8,039	8,924	120,622
Organic pollutants (benzene, dioxins, and furans, B(a)P)	66	143	141	147	140	154	99	60	52	69	1,071
Sum VOLY	326,553	304,919	295,277	288,791	276,507	276,219	265,051	231,354	199,935	219,378	2,683,984
Sum VSL	536,663	491,437	471,524	470,749	431,320	434,089	414,862	354,383	318,769	352,707	4,276,503

Source: European Environmental Agency (2024). How air pollution affects our health. <https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health>.

2. THE IMPACT OF AIR POLLUTION ON DECISION-MAKING

It is important to understand how air pollution affects decision-making to understand all possible ways in which it might affect economic and insurance purchase decisions. Some medical studies, such as Calderon-Garciduenas et al. (2008), show that a high level of PM_{I2.5} concentration affects cognitive abilities.⁵⁵ Motivated by these studies, Chew et al. (2021)⁵⁶ experimentally study the impact of PM_{I2.5} concentration on economic decision-making. The experiments were conducted in China during the five days of October 2012, when the pollution level was very high, but some variations were also recorded due to wind speed. The average level of PM_{I2.5} concentration during the experiment was extremely

⁵⁵ Calderón-Garciduenas, L., Mora-Tiscareño, A., Ontiveros, E., Gómez-Garza, G., Barragán-Mejía, G., Broadway, J., Chapman, S., Valencia-Salazar, G., Jewells, V., Maronpot, R. R., Henríquez-Roldán, C., Pérez-Guillé, B., Torres-Jardón, R., Herri, L., Brooks, D., Osnaya-Brizuela, N., Monroy, M. E., González-Maciel, A., Reynoso-Robles, R., Villarreal-Calderon, R., Solt, A. C., & Engle., R.W. (2008). Air Pollution, Cognitive Deficits, and Brain Abnormalities: A Pilot Study with Children and Dogs. *Brain and Cognition*, 68(2), pp. 117-127.

⁵⁶ Chew, S. H., Huang, W., & Li, X. (2021). Does Haze Cloud Decision Making? A Natural Laboratory Experiment. *Journal of Economic Behavior & Organization*, 182, pp. 132-161.

high, $288.5 \mu\text{g}/\text{m}^3$. However, during the third day of the experiment, the level of $\text{PMI}_{2.5}$ concentration fell from $250 \mu\text{g}/\text{m}^3$ to $30 \mu\text{g}/\text{m}^3$ due to the high wind speed.

The experiments measured several aspects of decision-making. The first one is related to choices involving risk and ambiguity. In risky choices, the decision-maker knows the probability of occurrence of different outcomes, while in ambiguity, the decision-maker knows what the possible outcomes are but does not know the probability of occurrence of these outcomes. The experiments aimed to elicit certainty equivalents of risky and ambiguous lotteries. The second aspect was related to intertemporal preferences and personal discount factor.

The third aspect of the experiments was to deduce the impact of air pollution on social decision-making. In a dictator game, player A decides how to split a certain amount of money between himself and player B. If player B accepts, the money is divided according to player A's proposal. If player B rejects, both players receive zero payoff. In the ultimatum game, player A chooses how to split a certain amount of money. At the same time, player B decides on the minimum acceptable offer (MAO). If player A's offer exceeds player B's MAO, the money is divided according to player A's proposal. Otherwise, both players receive zero payoff. Both players have a certain amount of money in a public good game. They should decide how much to contribute to the public good and how much to retain for their private consumption. The contribution for acquiring the public good is multiplied by 1.6, while the money retained for private consumption is multiplied by 1. In a sequential prisoner's dilemma, player A moves first, and player B moves second. Based on player B's choice, this player can be uncooperative, conditionally, or unconditionally cooperative.

The experiment's results on behavior in risk and ambiguity lotteries show that individuals increase their risk aversion due to the high concentration of $\text{PMI}_{2.5}$. An increase in ambiguity aversion over gains was recorded, but not over losses. Concerning intertemporal preferences, individuals are more impatient (exhibit present bias) with a higher level of air pollution.

In the dictator game, players of A-type (dictators) were willing to give less to respondents (players of type B). The division of the money in the ultimatum game was unaffected by the level of air pollution. In the public goods game, individuals reduced their contribution to acquiring the public good by 18% due to a $100 \mu\text{g}/\text{m}^3$ increase in $\text{PMI}_{2.5}$ concentration. In the sequential prisoner's dilemma game, the probability of uncooperative behavior increased significantly due to higher pollution. All these results imply that pollution reduces altruism in social decision-making. The most important result for further discussion in this text is that air pollution increases risk aversion and demand for health and life insurance.

3. DEMAND FOR LIFE INSURANCE

This section explains how demand for life insurance depends on air pollution and provides important theoretical background for subsequent discussion in the rest of the chapter. In contrast to other papers in this field, which are mainly empirical, Adetutu et al. (2024)⁵⁷ construct a theoretical model that explains the impact of air pollution on life insurance demand. The model is constructed in the Expected utility setup but the main conclusions also hold in the Prospect theory approach.

There are two states of nature. With probability p , the head of the household dies, and with probability $1-p$, the head is alive. The probability p is an increasing function of the level of air pollution λ , $dp(\lambda)/d\lambda > 0$. When the head of the household dies, the household has smaller consumption c_0 than when he is alive, c_1 , $c_0 < c_1$. The head of the household wants to insure his family against the risk of his death, and for this reason, he buys life insurance. The head of the household maximizes the following expected utility function:

$$\max_I p\beta u(c_0 + I - \pi) + (1-p)u(c_1 - \pi), \quad (1)$$

where $u''(\cdot) < 0$ is a concave utility function since the head of the household is risk averse. The parameter β captures the bequest motive. When $\beta=0$, there is no bequest motive and no incentive to buy life insurance, and the necessary condition for positive demand for life insurance is that $\beta>0$. The life insurance premium is denoted by π , and the insurance coverage is I . When the insurance premium is fair, the premium equals the expected loss, $\pi = pI$. However, the insurance company has to earn some positive profit, and the variable load factor $a > 0$ captures this unfair premium. On top of this, a fixed load factor $L > 0$ makes the insurance premium even more unfair. Hence, the unfair insurance premium in this model is $\pi = apI + L$. Adetutu et al. (2024) assume that the head of the household has a constant relative risk aversion utility function:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}, \quad (2)$$

where γ is the constant relative risk aversion parameter. Based on the previous assumptions, the head of the household maximizes the following expected utility:

$$\max_I p(\lambda)\beta \frac{(c_0 + I - ap(\lambda)I - L)^{1-\gamma}}{1-\gamma} + (1-p(\lambda)) \frac{(c_1 - ap(\lambda)I - L)^{1-\gamma}}{1-\gamma}. \quad (3)$$

⁵⁷ Adetutu, M. O., Odusanya, K. A., Rasciute, S., & Stathopoulou, E. (2024). Pollution Risk and Life Insurance Decisions: Microgeographic Evidence from the United Kingdom. *Risk Analysis*, 44, pp. 1907-1930.

The first-order condition yields the optimal amount of life insurance coverage:

$$I = \frac{\theta^{1/\gamma} (c_1 - L) - c_0 + L}{1 - ap(\lambda)(1 - \theta^{1/\gamma})}, \quad (4)$$

where $\theta = \frac{\beta(1 - ap(\lambda))}{a(1 - p(\lambda))}$. It is straightforward to conclude that the amount of life

insurance coverage is increasing in c_1 , which means that when the consumption in the state of nature when the head of the family is alive increases, the family has more wealth and buys more life insurance. In contrast, demand for life insurance is decreasing in c_0 . This implies that when the consumption in the state of nature increases when the head of the family is not alive is high, the family buys less life insurance. This result is intuitive; if the family has high consumption despite the head's death, there is less need for life insurance. The most important comparative statics result is that the partial derivative $\partial I / \partial \lambda$ can have any sign, and demand for insurance can increase or decrease with air pollution. Therefore, this model implies a non-linear relationship between insurance demand and pollution.

The results of the model are robust when the Prospect theory of Kahneman and Tversky (1979)⁵⁸ is used instead of Expected utility. Prospect theory is based on experimental results showing that individuals underestimate the probability of the occurrence of low-probability events and overestimate the probability of high-probability events. For this reason, the probability weights in the valuation of the prospect (lottery) are non-linear $\pi(p(\lambda))$ and $\pi(1 - p(\lambda))$, where $\pi(\cdot)$ is a non-linear function. The valuation function is different for gains and losses. Namely, the same absolute amount of gain relative to some reference income level increases the prospect's value less than the same absolute amount of loss reduces the prospect's value. In other words, individuals exhibit loss aversion. If we denote the change in income relative to the reference level of income by Δc , the valuation of gains and losses is:

$$v(\Delta c) = \begin{cases} (\Delta c)^\rho, & \text{for } \Delta c \geq 0 \\ -\psi(\Delta c)^\rho, & \text{for } \Delta c < 0 \end{cases}, \quad (5)$$

where $v(\cdot)$ is the valuation of gains and losses, $\rho < 1$ is the diminishing sensitivity parameter, and $\psi > 1$ captures the loss aversion. Thus, for gains

⁵⁸ Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47(2), pp. 263-291.

relative to the reference income level, the valuation is $(\Delta c)^\rho$, while for losses, the valuation is $-\psi(\Delta c)^\rho$.

By using all these assumptions, the maximization problem of the life insurance purchase decision in Adetutu et al. (2024) is:

$$\max_I \pi[p(\lambda)]\beta[I - ap(\lambda)I - L]^\rho - \pi[(1 - p(\lambda))]\psi[ap(\lambda)I + L]^\rho. \quad (6)$$

In the first part of (6), the gain is measured relative to the reference income c_0 , and the loss relative to the reference income c_1 . The maximization problem yields the optimal level of life insurance coverage, I . The most important comparative statics result in this case also shows that the sign of the partial derivative $\partial I / \partial \lambda$ can be either positive or negative, implying a non-linear relationship between air pollution and life insurance demand as in the model with expected utility maximization.

In the empirical part of the paper, Adetutu et al. (2024) use $PMI_{2.5}$ as the measure of air pollution. The reason is that these particles may cause respiratory and cardiovascular problems and lung cancer. The empirical results confirm previous theoretical findings on the non-linear relationship between air pollution and demand for life insurance. Namely, when air pollution increases above a certain threshold, which is considered dangerous for health, the demand for life insurance increases. In contrast, below this threshold value, when the level of air pollution increases, the demand for life insurance falls. The same pattern is identified when nitrogen dioxide (NO_2) measures the pollution level. Regarding the control variables in the regressions, demand for life insurance is higher among individuals with higher incomes, higher education levels, married individuals, and those holding other insurance policies.

4. NON-LINEAR AND HETEROGENOUS DEMAND FOR HEALTH INSURANCE

The same non-linear relationship between air pollution and demand for health insurance was determined in empirical papers. The impact of air pollution on the demand for health insurance in China was studied by Chang et al. (2018)⁵⁹. Health insurance policies in China have a cancellation option. The insurance policy can be canceled without cost within ten days after the insurance purchase. The air quality is measured by AQI (Air Quality Index). The impact of the AQI on demand for health insurance becomes statistically significant when the AQI

⁵⁹ Chang, T. Y., Huang, W., & Wang, Y. (2018). Something in the Air: Pollution and the Demand for Health Insurance. *Review of Economic Studies*, 85(3), pp. 1609-1634.

becomes larger than 150. When the AQI is in the region from 150 to 200 (unhealthy) and in the region from 200 to 300 (very unhealthy), demand for health insurance increases by 16.8% compared to days when the AQI is in the healthy region (below 50). When the AQI is above 300 (Hazardous), demand for health insurance increases by 23.4% compared to days when the AQI is in the healthy region.

There is another phenomenon that Chang et al. (2018) identified that confirms non-linear form of health insurance demand. Namely, when the AQI level falls relative to the AQI level when the insurance purchase decision was made, the probability of cancellation in the ten-day window increases. Specifically, when the AQI falls by one standard deviation relative to the purchase date, the probability of cancellation increases by 4%. It is important to emphasize that this cancellation decision is triggered by the relative difference in air quality between the cancellation decision day and the purchase day, not by the absolute level of air pollution. Only the current level of pollution has a significant impact on the demand for health insurance. In contrast, past pollution levels do not significantly impact the current demand for health insurance. There is no similar effect for other insurance policies. The reduction in the AQI has no significant effect on the decision to cancel other types of insurance policies.

Based on the empirical results, Chang et al. (2018) searched for a behavioral explanation of the identified phenomena. One explanation is based on the projection bias identified by Augenblick and Rabin (2019)⁶⁰ among others. According to this hypothesis, individuals buy health insurance when high pollution levels cause an adverse health shock and cancel health insurance if their health is better than in the period of insurance purchase. According to this hypothesis, these decisions are governed by the absolute level of air pollution. The second explanation is based on the salience hypothesis identified by Bordalo et al. (2013⁶¹, 2022⁶²). According to this hypothesis, individuals purchase health insurance when air pollution exceeds some benchmark value. In other words, individuals buy health insurance when there is a negative surprise (higher pollution) relative to the benchmark. In contrast, individuals cancel health insurance when there is a positive surprise (lower pollution) relative to the benchmark. The salience assumption implies that people buy more insurance

⁶⁰ Augenblick, N., & Rabin, M. (2019). An Experiment on Time Preference and Misprediction in Unpleasant Tasks. *Review of Economic Studies*, 86(3), pp. 941-975.

⁶¹ Bordalo, P., Gennaioli, N., & Shleifer, A. (2013). Salience and Consumer Choice. *Journal of Political Economy*, 121(5), pp. 803-843.

⁶² Bordalo, P., Gennaioli, N., & Shleifer, A. (2022). Salience. *Annual Review of Economics*, 14(1), pp. 521-544.

when pollution is higher than the average for that month in a year, while the projection bias predicts that people buy health insurance when pollution is high regardless of the benchmark value of the pollution level for that particular month. Another example is that if people follow salience behavior, they will increase their demand for health insurance on days with high pollution if these days are preceded by days with low pollution levels. If people follow projection bias behavior, they buy insurance when pollution is high and don't consider pollution in the preceding days when making this decision.

Wang et al. (2021)⁶³ study the impact of the AQI level on individuals' demand for health insurance for their children and parents in China. The first result of this empirical study is that the more severe the pollution level, individuals are more willing to buy health insurance for their children and less for their parents. Individuals with higher incomes have a higher demand for health insurance for their children and parents. Older individuals have a lower demand for health insurance for their children since children are more economically independent. People living in large, economically developed urban agglomerations have a higher demand for health insurance for their children than their parents. The reason might be that their parents already have good health insurance protection in large developed cities. Furthermore, the relationship between a city's GDP per capita level and the demand for children's health insurance is non-linear. Demand for health insurance for children first increases and then falls with GDP per capita. In contrast, the demand for health insurance for parents monotonically falls with GDP per capita. People with better financial education are more willing to buy health insurance for their children since they can better understand underlying risks. Finally, the demand for health insurance for children and parents is larger in regions with generally higher demand for all types of insurance.

Air pollution causes various diseases, increases health care expenditures, reduces workers' productivity, and increases their absence from work. The empirical research of Hou et al. (2024)⁶⁴ is based on the fact that temperature inversion causes more pollution. Temperature inversion is the phenomenon when the air temperature is lower at the surface than at higher layers of air, which induces a higher concentration of PM_{2.5} at the surface. This empirical research finds that 1% of the increase in temperature inversion frequency increases the

⁶³ Wang, Q., Wang, J., & Gao, F. (2021). Who is More Important, Parents or Children? Economic and Environmental Factors and Health Insurance Purchase. *The North American Journal of Economics and Finance*, 58, 101479.

⁶⁴ Hou, Z., Zhang, G., Lohmann, P., Kontoleon, A., & Zhang, N. (2024). The Effect of Air Pollution on Defensive Expenditures: Evidence from Individual Commercial Health Insurance in China. *Journal of Environmental Management*, 370, 122379.

concentration of PM_{2.5} particles by 2.52%. Furthermore, a 1% increase in PM_{2.5} concentration increases individual health expenditures by 11%.

Among different age groups, middle-aged individuals are the most responsive to the increase in pollution concentration, followed by younger individuals. Individuals in the oldest group are the least responsive. There are no significant gender differences regarding sensitivity to pollution. Paradoxically, less educated individuals are more sensitive to pollution. The explanation is that more educated individuals have higher health protection financed by their employers. In addition, less educated people are more exposed to polluted air during work due to the nature of their jobs. In accordance with other studies, married individuals are more responsive due to their preoccupation with their families' security. Finally, individuals living in urban agglomerations are more responsive due to higher exposure to pollution and higher costs of medical services in cities.

5. RISK PERCEPTION AND DEMAND FOR HEALTH INSURANCE

Risk perception related to air pollution plays an important mediating role in health insurance purchase decisions. Li and Tian (2024)⁶⁵ study the relationship between air pollution and demand for health insurance through the mediating effect of individuals' risk perception. This study finds a similar impact on control variables as in previous studies. Individuals with higher incomes demand more health insurance. Women are more sensitive to higher pollution than men and buy more health insurance. Residents in urban areas and regions with higher mortality rates are more sensitive to haze pollution.

The paper's main finding is that the increase in pollution in regions with high climate risk perception reduces the demand for health insurance. This counterintuitive result stems from the fact that increasing current pollution reduces demand for health insurance since residents try to mitigate this effect by buying more masks and air filters. In contrast to other papers, Li and Tian (2024) find that lagged pollution levels increase the demand for health insurance. This phenomenon of the lagged impact of pollution on decisions to buy health insurance mainly exists in regions with high climate risk perception.

The study also identifies spillover effects, namely that demand for health insurance depends not only on lagged pollution levels in the region but also on the lagged pollution levels in nearby regions. In the central and western regions

⁶⁵ Li, X., & Tian, Q. (2024). Haze Pollution, Climate Risk Perception and Demand for Commercial Health Insurance. *SAGE Open*, 14(2), 21582440241242544.

of China, the impact of air pollution on the demand for health insurance is not statistically significant. Nevertheless, this impact is statistically significant in eastern regions. This effect stems from higher income and higher levels of education of residents in eastern regions. The spillover effect is significant in the eastern and central regions of China, while it is not significant in the western regions of China.

The moderating effect of pollution perception on demand for commercial health insurance in China was studied by Sun et al. (2024)⁶⁶. This empirical study reveals that advertising of commercial health insurance and the behavior of friends and relatives significantly impacted the demand for commercial health insurance, which is moderated through pollution perception. The impact of friends' and relatives' behavior on pollution risk perception is more substantial for women than men. Advertising positively affected women's pollution risk perception and their intention to buy health insurance but negatively impacted men's perception. Furthermore, the impact of advertising and family and friends' behavior on risk perception and the intention to buy health insurance was stronger for individuals living in rural than for individuals living in urban areas. Finally, the air pollution level significantly affects pollution risk perception and increases the willingness to buy commercial health insurance. In contrast, the level of water pollution does not significantly impact pollution risk perception and willingness to buy commercial health insurance.

6. DEMAND FOR HEALTH AND LIFE INSURANCE BASED ON MICRO-DATA

Micro-data are based on information on individual household's decisions to buy health or life insurance. The impact of pollution on health and life insurance in China based on micro-data was studied by Zhao (2020)⁶⁷. The dependent variable in the empirical study is a binary variable that takes the value of 1 if a family has commercial health or life insurance. Otherwise, it has a value of 0. The independent variable is the AQI (Air Quality Index), which measures the concentration of sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), ozone (O₃), PM_{2.5}, and PM₁₀. The results of the empirical study reveal that a unitary increase in the pollution index increases the probability that a household buys either commercial health or life insurance by 17.5%.

⁶⁶ Sun, D., Chen, W., & Dou, X. (2024). Formation Mechanism of Residents' Intention to Purchase Commercial Health Insurance: The Moderating Effect of Environmental Pollution Perception. *Journal of Public Health*, 32(6), pp. 917-930.

⁶⁷ Zhao, W. (2020). Effect of Air Pollution on Household Insurance Purchases. Evidence from China Household Finance Survey Data. *Plos one*, 15(11), e0242282.

Concerning the control variables, households with a woman as the head of the family are 18.3% more likely to buy commercial health and life insurance than households with a man as the head. In addition, the former households have 11.7% higher expenditures on health and life insurance premiums than the latter households. As in previous studies, households with higher levels of education, higher incomes, and households in urban areas are more likely to buy commercial health and life insurance. Larger families are also more likely to buy commercial health and life insurance than small families. In contrast to other studies, households with more children under 14 years are less likely to buy commercial health and life insurance, possibly due to the more restrictive household's budget constraint. However, families with more children under 14 who buy commercial health and life insurance spend more on health and life insurance premiums than families with fewer children.

Air pollution's effect on health insurance demand is more substantial than on life insurance. The unit increase in the AQI index increases the probability of buying commercial health insurance by 10.71%, the likelihood of buying commercial life insurance by 7.95%, and the likelihood of buying other insurance types by 6.72%.

The most surprising result is that the level of $PM_{2.5}$ does not significantly impact the probability of buying commercial health and life insurance. This result might be explained by the fact that this study uses Logit and Poisson regressions, while other studies are mainly based on OLS or two-stage LS. Finally, Zhao (2020) finds that households are the most sensitive to the level of nitrogen dioxide (NO_2) and ozone (O_3).

Wang et al. (2021)⁶⁸ also used micro-data in their study, but the dataset is much richer than that of Zhao (2020). They study the impact of sulfur dioxide concentration (SO_2) on the probability of buying commercial health insurance in China. The dependent variable is a binary variable that takes the value of 1 if a household has commercial health insurance and 0 otherwise. Slightly more than 5% of the households in the sample possessed commercial health insurance. The independent variable is the level of SO_2 . The empirical results are based on the Probit and Tobit models. Both specifications show that the increase in air pollution measured by the concentration of SO_2 increases the likelihood that households buy commercial health insurance. This impact is larger for wealthier households and households with more children. Concerning the age of the head

⁶⁸ Wang, R., Zhang, L., Tang, T., Yan, F., & Jiang, D. (2021). Effects of SO_2 Pollution on Household Insurance Purchasing in China: A Cross-sectional Study. *Frontiers in Public Health*, 9, 777943.

of the household, the probability of buying commercial health insurance first increases with the age of the household's principal and, after that, falls. In contrast to some other studies, in this study, there is no significant difference between rural and urban households concerning demand for commercial health insurance. Finally, woman-led households are more sensitive to air pollution than man-led households.

Previous papers considered only commercial health insurance, while Chen and Chen (2020)⁶⁹ consider the impact of air pollution on both basic and commercial health insurance based on micro-data. Since 2009, China has been reforming its medical system, and from then, there has been a substitution between commercial and basic health insurance in favor of basic health insurance.

The dependent variable in this empirical research is a binary variable that takes the value of 1 when an individual has either commercial or basic health insurance and zero otherwise. When both types of insurance are considered together, 70% of individuals have some form of health insurance. Probit and two-stage LS regressions show a significant impact of air pollution on the demand for health insurance. Concerning the control variables, an individual's age, income, and level of education positively impact the demand for health insurance when the level of air pollution increases. In contrast to some previous studies, there are no significant gender differences regarding demand for health insurance.

Air pollution causes serious health problems and increases health expenses. It also negatively affects the labour force, reducing productivity and increasing absence from work due to illness. In the short run, individuals buy health and life insurance to protect themselves against these adverse effects of air pollution. However, from the long-run perspective, high air pollution may become a serious obstacle to further economic development, and ecological concerns related to reducing air pollution represent an important factor for long-run economic development.

⁶⁹ Chen, F., & Chen, Z. (2020). Air Pollution and Avoidance Behavior: A Perspective from the Demand for Medical Insurance. *Journal of Cleaner Production*, 259, 120970.

Chapter 3.

GREEN FINANCING UNIVERSE IN THE TIME OF GEOPOLITICAL SHIFTS

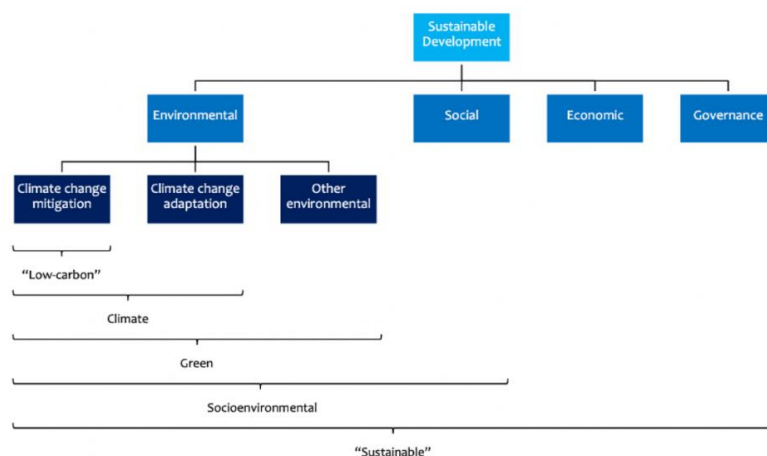
The term green finance refers to financial products and services that encourage environmentally friendly and sustainable investment alternatives and projects. Areas covered by this form of financing include, among others, the alternative energy sources, biodiversity conservation, water purification, waste management, green transportation, construction and agriculture. Green financing instruments direct financial resources towards companies, government, local authorities and individuals who, in their business and investment activities, support sustainability and reduce the negative impacts of their actions on the broader environment. Financial innovations that also characterise the area of environmentally responsible business activities facilitate the transition to a more efficient economy by enabling easier financing of projects that use available resources more rationally, reduce the emission of harmful gases and promote the use of alternative energy sources. Finally, the field of green financing creates new jobs and offers the possibility of environmentally conscious economic development.

1. THE GROWING NEED FOR GREEN FINANCING

The term sustainable finance refers to instruments and processes that generate value and financial assets in a way that meets the long-term needs of an inclusive and environmentally sustainable economy. The difference is made between the terms “sustainable”, “green” and “climate” finance.⁷⁰ Sustainable finance is the most inclusive term, including social, environmental and economic aspects of financing activities. Green finance refers to financial instruments whose proceeds are used for environmentally friendly and sustainable projects and initiatives, environmental products and policies. The unique goal is a transition towards a low-carbon, sustainable and inclusive economy. Climate finance refers to climate change mitigation and climate change adaptation instruments, strategies and actions. The following Figure 1 presents these three categories of finance.

⁷⁰ United Nations Environment Programme (2016). *Inquiry: Design of a Sustainable Financial System*, Nairobi: UNEP, https://wedocs.unep.org/bitstream/handle/20.500.11822/10603/definitions_concept.pdf?sequence=1&isAllowed=y

Figure 1. Sustainable finance and development subcategories



Source: United Nations Environment Programme (2016), *op. cit.*

The negative consequences of accelerated climate change shape modern business and impose significant investments by the government and private sector in the research and development of new forms of green technologies and production processes. As Morgan Stanley predicts, it will be necessary to spend more than USD 50 trillion on a global level in order to meet the requirements of the Paris Agreement and achieve the status of zero emissions of harmful gases, resulting in the greenhouse effect.⁷¹ The process of transformation of production and operational processes of companies and their direction towards ecologically sustainable businesses requires significant financial resources. Governments are aware of the growing financial needs for these purposes at the national, local and sectoral levels.⁷² In these circumstances, the concept of green financing arises.

2. GREEN FINANCING INSTRUMENTS

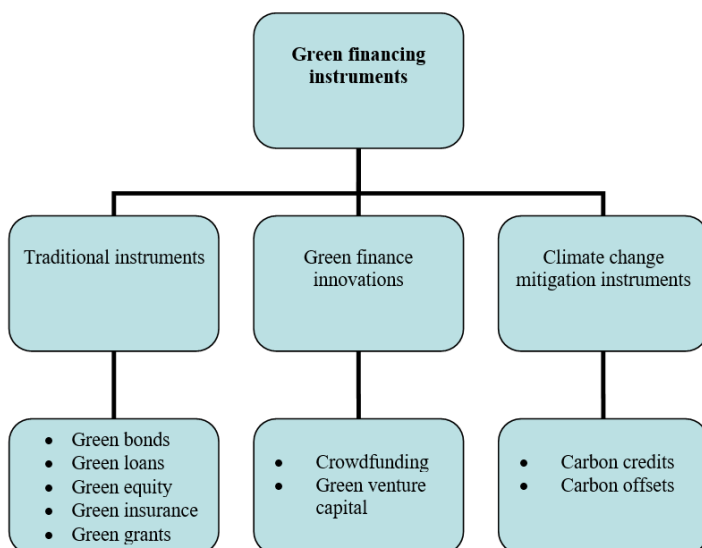
Green financing instruments are developed over time on the basis of classical financial instruments. The key difference between them is that green instruments have a dual purpose - achieving returns on invested funds (often accompanied by

⁷¹ Klebnikov, S. (2019). Stopping Global Warming Will Cost \$50 Trillion: Morgan Stanley Report. *Forbes*, <https://www.forbes.com/sites/sergeiklebnikov/2019/10/24/stopping-global-warming-will-cost-50-trillion-morgan-stanley-report/?sh=2bb4b1eb51e2>

⁷² Janković, I., Vasić, V., & Kovačević, V. (2022). Does transparency matter? Evidence from panel analysis of the EU government green bonds. *Energy Economics*, 114, 106325, <https://doi.org/10.1016/j.eneco.2022.106325>

positive tax treatment)⁷³ while preserving and protecting the natural environment and reducing the negative effects of climate change. Green finance instruments can be classified into three key categories – traditional instruments, green finance innovations and climate change instruments.⁷⁴ The following Figure 2 shows the key categories and the individual instruments that belong to each of them.

Figure 2. Green financing instruments



The category of traditional green financial instruments includes green bonds, green loans, green equity, green insurance instruments and green grants and subsidies. Green financing innovations include crowdfunding and green venture capital. Finally, a special segment of the market consists of instruments focused on climate change mitigation, which include carbon credits and carbon offsets. In the following, the characteristics of each mentioned instrument and/or mechanism of green financing will be presented.

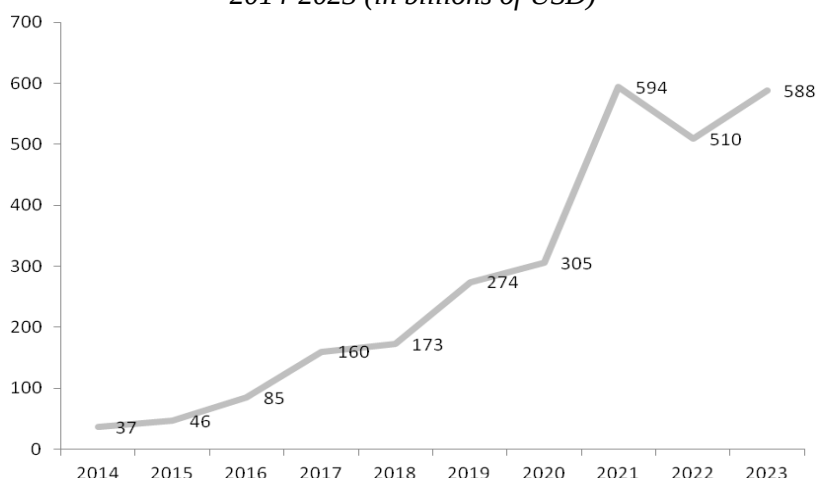
⁷³ Janković, I., Kovačević, V., & Ljumović, I. (2022). Municipal Green Bond Yield Behaviour. *Ekonomika preduzeća*, LXX(3-4), pp. 206-214; Janković, I., Vasić, V., & Basarić, J. (2022). Zelene obveznice u EU – Analiza determinanti prinosa. In: *Proceedings of XLIX International Symposium on Operational Research SYM-OP-IS 2022*, Mladenović, Z., Stamenković, M. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 155-160.

⁷⁴ Chatterjee, D. (2023). 7 popular Green Financing instruments you need to know about. *Neufin*, <https://neufin.co/blog/green-financing-instruments>

Green bonds

Green bonds are debt financial instruments that are issued with the aim of collecting financial resources for the realisation of environmentally responsible projects. They can be issued by domestic and international financial institutions⁷⁵, companies, states and local governments. The first green bond was issued by the European Investment Bank in 2007. During 2008, the World Bank started issuing green bonds, collecting funds to reduce the negative consequences of climate change. Since then, until today, the green bond market has been growing significantly.⁷⁶ According to data from the Climate Bonds Initiative, USD 870 billion of green, social and sustainability bonds were issued globally in 2023, 3% more than the year before. The cumulative observed value of issued green, social and sustainability bonds thus reaches USD 4.4 trillion. Of the total stated amount of bonds issued in 2023, 68% are green bonds, reaching a value of USD 587.7 billion, which is an increase of 15% compared to 2022. Figure 3 shows the value of issued green bonds in the period from 2014 to 2023.

Figure 3. The value of issued green bonds at the global level in the period 2014-2023 (in billions of USD)



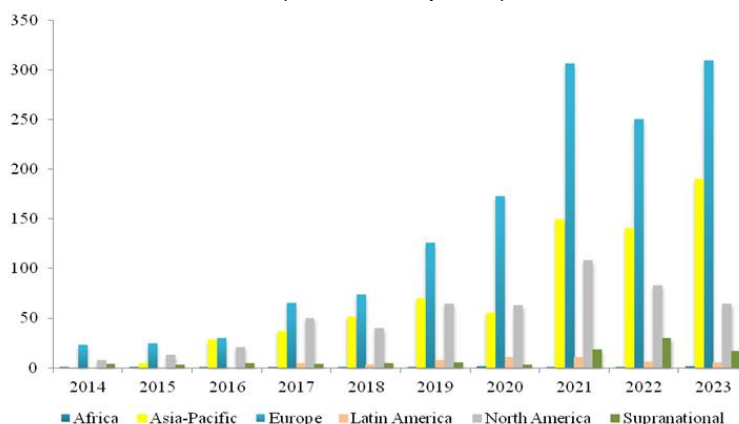
Source: Climate Bonds Initiative (2025), <https://www.climatebonds.net/market/data/>

⁷⁵ Kovačević, V., Janković, I., Vasić V., & Ljumović, I. (2023). Does Transparency Pay Off for Green Bonds' Issuers? Evidence From EU State Agencies' Green Bonds. *Economics of Agriculture*, 70(4), pp. 997-1007.

⁷⁶ Janković, I. (2023). Tržište zelenih obveznica – stanje i perspektive. In: *Ekonomska politika u Srbiji i svetu u 2023. godini*, Zec, M., Šoškić, D., Radonjić, O. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 119-129.

Regarding the regional distribution, Europe is the prime issuer in terms of the amounts issued per year, followed by Asia and North America. Figure 4 presents the regional distribution of green bonds' amounts issued in the previous period.

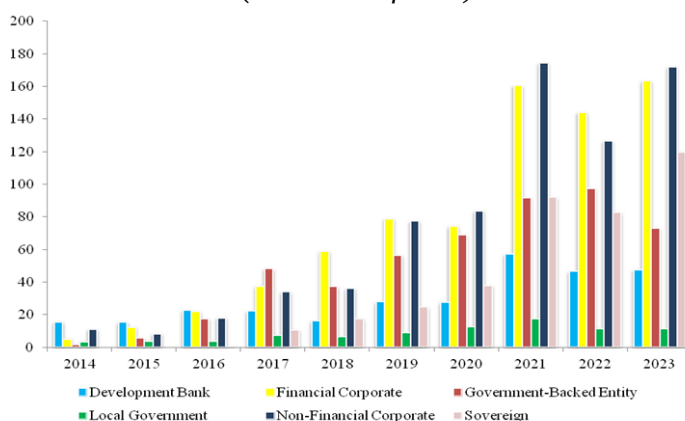
Figure 4. The amount of issued green bonds per region in the period 2014-2023 (in billions of USD)



Source: Climate Bonds Initiative (2025). <https://www.climatebonds.net/market/data/>

Among different types of issuers, the largest issuers in the last 5 years are non-financial corporations and financial corporations, followed by the government and government-backed entities. Figure 5 depicts the most significant green bond issuers.

Figure 5. Green bonds issued by type of issuer in the period 2014-2023 (in billions of USD)



Source: Climate Bonds Initiative (2025). <https://www.climatebonds.net/market/data/>

Green bonds help mobilise financial resources from individual and institutional investors and direct them towards projects and ventures that focus on sustainable energy sources, low-emission economies and other environmentally responsible alternatives. At this moment, these financial instruments are issued in more than 50 countries around the world.

Green loans

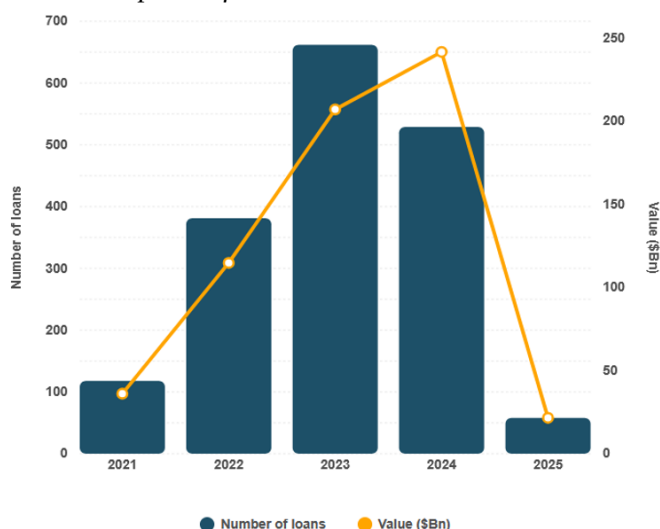
Green loans help individuals, businesses and governments to finance environmentally responsible projects and business ventures. It is a special type of loan according to its purpose, which is essentially twofold. They help finance profitable and environmentally responsible, so-called green projects. As a result, they are often characterised by a lower interest rate compared to similar "non-green" or traditional loans.

Seen from the perspective of the broader population, green loans can help finance the installation of solar panels, the purchase of electric vehicles, the construction of cisterns for rainwater collection, and the like. This encourages a more efficient, sustainable and quality way of living. When it comes to companies that are starting to introduce green practices into their operations, there is often a misconception that this process is necessarily accompanied by higher costs and a negative impact on their profitability. Green loans can help large companies and small and medium-sized enterprises to switch to a sustainable way of doing business and at the same time gain an advantage compared to traditional competitors by signalling to clients, partners and investors that they take into account the wider environmental impact of their activities.

The principles that provide guidelines for structuring green loans, Green Loan Principles, were developed by representatives of leading financial institutions active in the global credit market and aimed at promoting the development and integrity of green loans as a special type of financial instrument. However, in order for these principles to be applied in practice, it is necessary for all markets to have developed standards and a clear taxonomy of green loans in order to avoid abuses in sustainable financing (greenwashing).

Publicly available data on approved green loans are shown in Figure 6. According to Environmental Finance Data, the value of approved green loans in 2024 was USD 855.9 billion.

Figure 6. Number and value (in billions of USD) of approved green loans in the period from 2021 to March 2025



Source: Environmental Finance Data (2025). <https://efdata.org/>

Green equity

Green bonds are nowadays well-known and have been used for a long time. Green equity is a younger financing vehicle that aims to support the green transition. It attracts green investors to invest in businesses that respect sustainability principles. The green equity designation label is granted to companies that have 50% or more of their revenues and investments that are assessed as green. Companies that operate in the green sector are oriented towards circular economy, recyclable products, usage of renewable resources, protection of the ecosystem, biodiversity preservation, efficient land use and overall positive impact on the environment.

In March 2023, the World Federation of Exchanges published the WFE Green Equity Principles, which is the first global framework that can be used by stock exchanges in establishing green offerings for listed equities.⁷⁷

Broader performances of green equity are followed through specialised green market indices. The following Table 1 presents green equity indices – their definitions and largest constituents.

⁷⁷ Sanches, C. (2024). Green Equities: Capital Markets as a Force for Good. *Focus*, <https://focus.world-exchanges.org/articles/green-equities-b3>

Table 1. Green equity indices

<i>Provider</i>	<i>Index</i>	<i>Partner</i>	<i>Green Definition</i>	<i>Number of stocks</i>	<i>Market capitalization (US\$)</i>	<i>3 largest holdings</i>
<i>Dow Jones</i>	DJ Sustainability World	SAM	top 10% in each sector, of the largest 2,500 companies in the base index based on long-term economic, environmental and social criteria	342	9800bn	IBM, GE, Nestle
<i>FTSE</i>	FTSE4Good	Eiris	including environmental and climate change factors	730 (global)	12900bn	Apple, Microsoft, Nestle
	Environmental Opportunities	Impax	environmental business activities, incl. renewable & alternative energy, energy efficiency, water technology, waste & pollution control	475	1593bn	
	Environmental Technology	Impax	green technology, renewable & alternative energy, energy efficiency, water technology and waste & pollution control	50	100bn	Novozymes, Stericycle, Pall Corp
	CDP Carbon Strategy 350 (UK)	CDP, ENDS Carbon	track base index but reduce exposure to carbon risk	<350	Similar to FTSE 350	BP, National Grid, Anglo American
<i>MSCI</i>	MSCI World ESG Index	MSCI / RiskMetrics	best-of-class approach relative to sector peers	790	11700bn	IBM, Procter & Gamble, J & J
	MSCI Global Environmental	KLD	companies derive over 50% of their revenues from products and services in of five environmental themes: alternative energy, clean technology, sustainable water, green building, and pollution prevention.	167	413bn	ABB, Emerson Electric, Schneider Electric
	MSCI Global Climate	KLD	100 leaders in mitigating the causes or the impact of climate change (Renewable Energy, Future Fuels, and Clean Technology & Efficiency); equally weighted	100	2.4bn	Int. Power, Clean Energy Fuels, Owens Corning
<i>S&P</i>	Global Eco		clean energy; water; environmental services/waste management	40	178bn	Waste Management, Danaher, Geberit
	Clean Energy		clean energy producers; clean energy technology & equipment providers	30	60bn	
	S&P U.S. Carbon Efficient	Trucost	track base index whilst reducing exposure to carbon emissions by up to 50%	<375	Similar to S&P 500	Apple, Chevron, Procter&Gamble
	S&P IFCI Carbon Efficient	Trucost	track base index whilst considerably reducing exposure to carbon emissions	>500	Similar to S&P/IFCI LargeMidCap	Samsung, Itau Unibanco, Vale
<i>BNEF</i>	Wilderhill New Energy Global Innovation	WilderHill	innovative technologies and services focus on the generation and use of cleaner energy, conservation, efficiency and the advancement of renewable energy in general	97	187bn	Contact Energy, Verbund, Ormat
<i>HSBC</i>	HSBC Global Climate Change Benchmark		generate revenues, on a supply chain basis, from the provision of goods, products and services directly linked to the industrial shift towards a low carbon economy	342	682bn	Siemens, ABB, Honeywell
	HSBC Investable Climate Change		climate change related revenue is more than 50 per cent of the total revenue of the company	50	147bn	Waste Management, Fortum, EDF
<i>Markit</i>	Markit Carbon Disclosure Leadership	CDP	tracks the performance of companies according to the CDP annual scores	569 (global)	Similar to FTSE All World	Exxon Mobil, Microsoft, J&J
<i>NASDAQ</i>	NASDAQ OMX Green Economy Index	SustainableB usiness.com	13 'green economy' sectors (US)	417	1271bn	Cisco, EMC, ABB

Source: Inderst, G., Kaminker, C., & Stewart, F. (2012). *Defining and Measuring Green Investments: Implications for Institutional Investors' Asset Allocations*. OECD Working Papers on Finance, Insurance and Private Pensions, No. 24, OECD Publishing, p. 23.

A special form of green equity investing is presented through green funds that collect available financial resources from both individuals and institutions and channel them towards stocks of green-labelled companies. Green equity investments are often supported by public, international and development finance institutions.

IFC published the Approach to Greening Equity in Financial Institutions in September 2020, with a goal to end equity investments in financial institutions that do not have a plan to exclude investments in coal extraction-related activities. This is the first step in reshaping IFC's equity investment portfolio. The approach requires IFC's equity partners to increase climate-related lending to 30% and reduce exposure to coal-related projects to 5% by 2025 and to zero (or near zero) by 2030.⁷⁸

Green equity is also gaining popularity at the Green Climate Fund, the biggest multilateral climate fund. Though equity investments comprise only 7% of the USD 10.2 billion of overall investments in April 2022, the fund management intends to increase its share.⁷⁹

Green insurance

Green insurance aims to encourage sustainable production and consumption by providing lower insurance premiums to actors in the field of green business. At the international level, financial institutions are focusing on insurance services and products that are linked to sustainability. This is especially the case after the publication of the Principles for Sustainable Insurance by UNEPFI, which defines how insurance companies should contribute to the sustainable development agenda by helping them to better and more accurately quantify risks and provide adequate coverage for green projects.

One of the challenges in securing green loans is the absence of clear definitions of what exactly constitutes a specific green product that is financed by a loan. This also makes it difficult to offer an adequate follow-up protection product. One such example is electric cars. Although it is known that electric vehicles pollute the environment to a lesser extent compared to traditional vehicles, they still have a negative environmental impact. Lithium batteries used to power

⁷⁸ Geary, K., Schalatek, L., & Brightwell, R. (2022). *Putting people and planet at the heart of green equity*. Washington, DC: The Heinrich Böll Foundation, <https://us.boell.org/sites/default/files/2022-04/Green%20Equity%20Updated.pdf>, pp. 14-15.

⁷⁹ Ibid, p. 10.

electric cars create a significant volume of environmental waste that is difficult to safely dispose of, store or recycle. So, even when we have in front of us the so-called green product, the question arises whether it is completely green. This makes it difficult to offer adequate insurance products and correctly measure the accompanying insurance premium.

At the same time, green insurance is vital to encourage the further development of green products and services, especially in developing countries. Significant exposure to climate risks threatens key sectors in economies that rely heavily on the agricultural sector. The impact of droughts, floods, significant temperature changes, hurricanes and other weather disasters is encouraging an increasing number of agricultural producers to request insurance services for their agricultural plots and crops. Green insurance promotes sustainability in agriculture by offering a variety of customised insurance products and services with an acceptable level of associated premiums.⁸⁰ Finally, green insurance encourages companies that generate harmful effects on the environment to internalise the costs of their negative environmental impact, thereby better managing overall negative environmental externalities.

Green grants and donations

Green grants and donations are aimed at encouraging local communities and the private sector to initiate projects that enable reducing the impact or adapting to the negative consequences of climate change, effective management of local natural resources and innovative approaches to environmental protection. Green donations can be offered by the state, philanthropic organisations, private foundations and non-governmental organisations. Green donations are also directed to research centres and universities to encourage research on climate change and sustainable development. This helps to close the financial gap for projects that have a good purpose but are, from a financial point of view, unprofitable, i.e. without return on invested funds.

Examples of institutions operating in this sphere are, for example, Global Greengrants Funds⁸¹, which through a bottom-up approach encourages the involvement of local communities in the implementation of innovative strategies to combat the effects of climate change, as well as the Green Climate Fund

⁸⁰ Janković, I. (2023). Green Bonds and Insurance – Complementary Tools to Address Climate-Related Risks. In: *Challenges and Insurance Market's Responses to the Economic Crisis*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 215-230.

⁸¹ <https://www.greengrants.org/>

formed under the auspices of the UNFCCC in 2010, which primarily directs financial aid to the least developed countries.⁸²

Green crowdfunding

Crowdfunding is a process in which companies or entrepreneurs collect financial resources for their business activities from a large number of investors, each of whom usually invests a small amount of money without the help of traditional financial intermediaries. The investment may be philanthropic, or a certain return may be expected, which may be financial, social and/or environmental. In the absence of access to traditional financing mechanisms, this form of fundraising can help green business ventures start their operations. In order for the green crowdfunding platforms to be successful in fundraising, they must clearly present the environmental and climate goals of the venture being financed. Also, they differ according to whether they are exclusively donor-oriented or collect funds in the form of equity or in the form of a loan. Investors' expectations about the type and amount of possible return on invested funds also depend on this. Accordingly, green companies must be able to clearly demonstrate the expected financial and environmental returns resulting from their activities in order to attract a greater number of investors.

Crowdfunding platforms certainly carry certain risks. They differ according to the level of management skills and operational standards, and as they become more and more numerous, it becomes difficult for investors to choose a reliable investment alternative.⁸³ Also, the inflow of funds in such investment alternatives is very volatile and sensitive to economic shocks. Finally, a large number of countries do not have developed regulations covering the field of crowdfunding.

Green venture capital

Green venture capital deals with the financing of projects and business ventures that develop sustainable technologies that ensure environmental protection and combat the negative consequences of climate change. The sectors in which the capital collected in this way is directed include energy, waste management, transport, construction and other related areas. It is about those segments of the mentioned activities that have difficult access to other sources of financing. Green startups focused on new technologies have difficulty obtaining capital

⁸² <https://www.greenclimate.fund/>

⁸³ Yin, Z., Huang, G., Zhao, R., Wang, S., Shang, W. L., Han, C., & Yang, M. (2024). Information disclosure and funding success of green crowdfunding campaigns: a study on GoFundMe. *Financial Innovation*, 10(1), p. 147.

from traditional sources of financing due to the high risks associated with this type of investment.

In the last three years, investments in the field of sustainable technologies have made up over 25% of all investments financed by venture capital. The transport sector, which accounts for about 20% of all emissions of harmful gases at the global level, accounts for over 60% of all investments in the field of green technologies. On the other hand, sectors such as sustainable agriculture, construction and industry do not have enough financial resources to green their production processes. Directing financial resources to these areas would speed up the process of reducing harmful gas emissions, while all pioneers in the area would gain comparative advantages both in terms of achieving the set environmental and financial goals.

State interventions can contribute to increasing investor confidence in the field of green entrepreneurial investment. Traditional government subsidy schemes in many countries still favour traditional sectors of the economy, while the absence of tax incentives for green startups may signal a low commitment to environmental and climate issues. All of the above often discourages environmental investment activities supported by venture capital. The absence of regulatory frameworks for green investments in the markets of a significant number of countries creates uncertainty for large institutional investors as well. In order to encourage green entrepreneurial investment, it is necessary to define a set of standards that define what green sectors are and to ensure stable capital flows to these sectors so that financed projects are essentially sustainable. On the other hand, there are markets, such as the USA and China, which are characterised by tax breaks and credits for companies that are focused on green economic areas.

Carbon credits and carbon offsets

At the climate change summit in Glasgow COP26 in 2021, the participating countries agreed on the creation of a global market for carbon credits. One carbon credit allows a specific company to emit up to one ton of carbon dioxide into the atmosphere. Based on the efforts made to make their operations more environmentally responsible and external verifications, companies are awarded a certain number of carbon credits that enable a limited amount of environmental pollution. Companies can sell unused carbon credits and use the collected funds to additionally finance environmentally sustainable activities. The supply of loans decreases every year, encouraging companies to reduce the level of harmful gas emissions and adapt their operations to environmentally friendly patterns.

The instrument called carbon offset refers to the removal/storage of up to one ton of already emitted harmful gases from the atmosphere. The goal of the carbon offset is to cancel out part of carbon dioxide emissions through funding of projects such as tree planting or investments in renewable energy. They help reduce the carbon footprint, having in mind that some emissions are at the moment unavoidable.

Table 2. Characteristics of carbon credits and carbon offsets

Carbon credits	Carbon offsets
• They can be traded by large companies and countries • They enable the emission of up to one ton of carbon dioxide per one credit • Trading is regulated and supervised by the state	• Available to individuals, small and large businesses • They support projects that remove harmful gases already emitted into the atmosphere • Trading on a voluntary basis

Source: Author's presentation

The market of the mentioned carbon instruments provides an opportunity for developing countries to improve their socio-economic development in the process of transition to a sustainable economy.

3. FUTURE STEPS IN THE DEVELOPMENT OF GREEN FINANCE UNIVERSE

Adequate regulatory support is of key importance for the development of green forms of financing and the transition of both the public and private sectors towards sustainable development. The set of necessary steps includes, among others, the following.

The first step involves increasing the state's fight against climate change and the development of specific policies and strategies that are dedicated to achieving specific environmental goals. The existence of developed green policies, strategies and action plans broadcasts a message to the investment public that a specific country is committed to long-term sustainable development. Concrete financial support in the form of tax exemptions, donations and subsidies for ecologically sustainable investments increases the confidence of investors and can result in the growth of green investments.

The second step refers to the development of classification systems, the so-called green taxonomy, which clearly defines what makes a product and service green and sustainable. This type of classification at the national and international level makes it easier for regulators, companies and investors to adequately and uniformly assess the environmental impact of business activities and investments. In financial markets, the developed green taxonomy reduces the level of information asymmetry and encourages investors to invest available surpluses in undeniably green projects and initiatives. Companies become aware of the concrete environmental impact they generate with their operations and possible permitted alternative courses of action. Green taxonomy reduces the risk of abuse in the financing and investment process. It encourages standardisation in the process of reporting on the environmental impact of business and thus enables investors to make an informed decision about investing funds.

The third step refers to the connection of individual markets with the international market of carbon financial instruments that contributes to a more effective reduction of harmful gas emissions and the harmonisation of prices of carbon instruments among different jurisdictions. In order to achieve this kind of integration, international cooperation and standardisation of permitted levels of harmful emissions, as well as adequate supervision of the process, are necessary.

Finally, in countries that issue green bonds, it is desirable to include them in the relevant international bond indices, which indirectly verify the quality of the mentioned instruments and attract more international investors to these markets.

4. POLICY ACTIONS IN TIMES OF GEOPOLITICAL SHIFTS

Policymakers are obliged to create a regulatory landscape that promotes green finance. That includes creating green finance policies and encouraging investments in environmentally friendly and socially responsible projects. These policies should be followed by incentives that support green finance initiatives in the financial sector. They should develop policies that result in reduced emissions, encouraging companies to reduce their carbon footprint.

Policymakers should create tools and frameworks for the assessment and mitigation of risks, making financial systems resilient to environmental shocks,

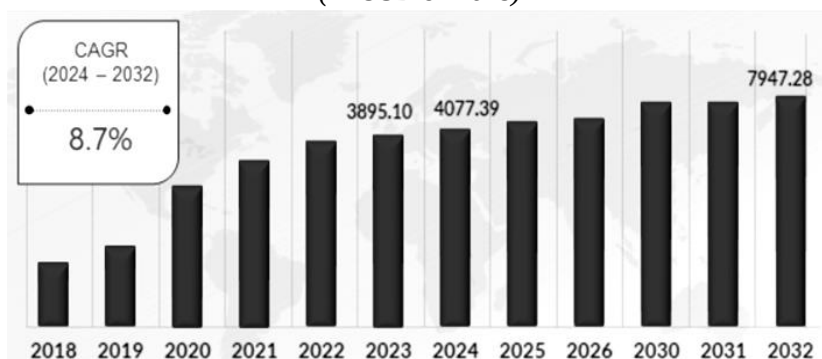
particularly climate change. They should promote the development and adoption of sustainable technologies.⁸⁴

Understanding how the latest geopolitical factors impact the green universe on the global, regional and local levels is of tremendous importance. Policymakers should customise green finance policies to address the specific needs and challenges of each concrete geographical area.

5. THE FUTURE OF GREEN FINANCING

According to the latest forecasts, the green finance market is expected to grow at a rate of approximately 8.7% p.a. in the forecast period (2024-2032), reaching the value of USD 7.95 trillion by 2032 (please see Figure 7).⁸⁵

*Figure 7. The green finance market size in the period 2018-2032
(in USD billions)*



Source: Dhapte (2025), *op. cit.*

Key challenges the green finance market is still facing include the lack of standardisation, often limited data availability and high transaction costs. On the other hand, key opportunities are seen in increasing government support, growing demand for sustainable investments and technological advancements.

Latest trends in the green finance market indicate a shift towards integrated sustainability reporting, the development of green Fintech solutions, and rising

⁸⁴ Fu, C., Lu, L., & Pirabi, M. (2024). Advancing green finance: a review of climate change and decarbonization. *DESD*, 2(1), <https://doi.org/10.1007/s44265-023-00026-x>, pp. 5-6.

⁸⁵ Dhapte. A. (2025). Green Finance Market. *Market Research Future*, <https://www.marketresearchfuture.com/reports/green-finance-market-24469>

cooperation between financial institutions and non-governmental organisations to promote sustainable finance strategies and actions. Through a focus on these emerging trends, market participants and stakeholders can capitalise on the growing demand for green finance instruments, contributing to a more sustainable financial world.

Chapter 4.

DO CAT BOND YIELDS PREDICT FUTURE CATASTROPHIC EVENTS?

Rare events can generate substantial losses for insurance companies, particularly when such events are systemic. Natural disasters represent economy-wide phenomena that typically result in significant insurance outflows and, consequently, elevate the liabilities of reinsurance companies tasked with hedging rare-event risks for primary insurers. The construction of tradable portfolios replicating the behavior of factors underlying rare events, such as natural catastrophes, is fundamental to effectively hedging catastrophic risks and securitizing associated losses. These portfolios provide a basis for synthesizing various securities featuring catastrophe-linked payoffs (e.g., D'Arcy & France, 1992; Cummins et al., 2002; Harrington & Niehaus, 2003; Nowak et al., 2012). Among these instruments, the catastrophe ("CAT") bond is the most prominent, functioning as a derivative wherein the underlying "asset" comprises a composite of variables that reflect property losses indemnified by insurance companies.

A CAT bond is structured similarly to a corporate bond, wherein investors provide principal in exchange for periodic coupon payments and the return of principal at maturity, contingent upon the non-occurrence of a predefined catastrophic event. A CAT bond functions as a risk transfer instrument, offering protection against indemnity payments associated with a specified peril, as defined by a contractual "trigger." The trigger is explicitly stipulated within the bond covenants and may be based on the exceedance of a predetermined loss threshold, an index value, or specific geophysical or meteorological parameters. CAT bonds typically have maturities ranging from one to five years. A default event is declared if the triggering conditions are satisfied during the bond term. The default event permits the issuer to access the collateralized principal to finance losses arising from the covered event.

The capital raised through CAT bond issuance is generally invested in low-risk assets, such as money market funds or highly rated short-term instruments, serving as a dedicated collateral pool to secure potential claims. Following the 2008 Global Financial Crisis, particularly in the aftermath of the Lehman Brothers' bankruptcy, industry practices evolved significantly. Before the crisis, issuers frequently entered into total return swap agreements with financial institutions to manage investment returns on the collateral pool. However, the systemic failure of counterparties during the crisis prompted a widespread shift

toward fully collateralized structures utilizing independently managed investment vehicles, thereby mitigating counterparty credit risk inherent in earlier CAT bond arrangements. This environment made CAT bonds increasingly attractive to investors seeking alternative sources of return, prompting a surge in issuance and pushing total outstanding volumes to nearly USD 10 billion before the crisis (Polacek, 2018).

Following the crisis, the CAT bond market experienced a temporary contraction, primarily due to counterparty exposures involving failed investment banks participating in collateral arrangements for several significant transactions. By the end of 2009, this challenge was addressed by adopting more robust and transparent collateral structures, restoring investor confidence and revitalizing market growth. Over the subsequent decade, the CAT bond market expanded substantially, with outstanding issuance more than doubling. This growth has been partly driven by persistently low global interest rates and a scarcity of high-yield opportunities in conventional fixed income markets. Furthermore, CAT bonds' low correlation with traditional asset classes has enhanced their appeal as portfolio diversification and risk-hedging tools. Recent advances in pricing methodologies and catastrophe risk modeling have also supported their development as a recognized investment class (Bauer et al., 2010; Bauer et al., 2013; Božović, 2021a; Božović, 2021b; Beer & Braun, 2022).

Today, the CAT bond market represents a complex and mature ecosystem involving various participants across the issuance and investment spectrum. On the supply side, large global reinsurers—such as AIG, Munich Re, Swiss Re, and USAA—remain the dominant issuers. However, government agencies, pension funds, and other institutional entities contribute to market supply (Edesess, 2015). On the demand side, institutional investors comprise the core investor base, particularly pension and hedge funds. In addition to these traditional actors, the market is supported by structuring and modeling agents, credit rating agencies, and specialized index providers who facilitate the design, assessment, and monitoring of CAT bond performance.

This chapter studies the informational content of CAT bond yields. In particular, it addresses whether these yields predict future catastrophic events. We approach this question by analyzing the dynamic association between CAT bond yields and the realized catastrophic losses they were supposed to hedge. The results indicate that market yields are moderately predictive of future catastrophic losses. Despite the specialized and complex nature of predictive information related to catastrophic events, the evidence supports the view that CAT bond markets efficiently accumulate diffuse information regarding future catastrophic losses.

The research topic falls into a growing literature on the market for catastrophe risk. Froot (2001), for example, offers a broad perspective on the subject. CAT bonds on average have excess spreads over comparably rated corporate bonds, forming the so-called *excess premium puzzle* (Lee & Yu, 2002; Cummins, Lalonde, & Phillips, 2004). Our research question is similar to that of Zhao & Yu (2020), who used panel data to study the predictive ability of individual CAT bond yields on future catastrophe losses in the United States. However, unlike them, our analysis focuses on a single value-weighted CAT bond yield series and overall losses, with a different methodological approach and set of control variables. It also does not focus on comparison to prediction markets.

The remainder of this chapter is organized as follows: Section 1 describes the data used in the empirical analysis. Section 2 presents the methodology. Section 3 shows and discusses the empirical results. Section 4 concludes.

1. DATA

Our analysis focuses on the U.S. data, given that they are the only comprehensive data related to CAT bond markets and catastrophe losses. To this end, we use several sources. Our primary variable of interest captures economic losses from weather and climate disasters affecting the U.S. between 1980 and 2024. The data on weather and climate disasters are available from the National Centers for Environmental Information, which are part of the National Oceanic and Atmospheric Administration (NOAA). They are updated quarterly and contain disaster descriptions, types (drought, flooding, freeze, severe storms, tropical cyclones, wildfires, and winter storms), begin and end dates, losses (raw and CPI-adjusted) in millions of dollars, and deaths.

As we are trying to measure the association between catastrophe losses and CAT bond yields, we use the weekly value-weighted CAT bond market yield data from Artemis. CAT bond yields represent the sum of the insurance risk spread derived from the premium paid for the coverage, and the yield of the collateral assets covering a specific CAT bond transaction (here assumed to be 3-month U.S. Treasury Bills). Apart from the insurance risk spread and the collateral yield, the Artemis data also contains expected losses, proportional to the probability of the unit monetary loss. To obtain the market weight of each CAT bond, its nominal value is divided by the total market volume. The data contains 743 observations between October 8, 2010 (week 41 of 2010) and December 27, 2024 (week 52 of 2024). We match these observations with the economic loss data from the NOAA database by associating each catastrophe event with the week of its beginning date. We follow previous studies and combine the U.S. catastrophe variables and CAT bond yields with additional control variables capturing the impact of capital

market and insurance market developments. We use the U.S. market return over the risk-free rate, available from Kenneth French's Data Library; Moody's seasoned Baa corporate bond yield relative to the constant-maturity yield on 10-year U.S. Treasury Notes, available from the FRED Database of the St. Louis Fed; the FR Global Reinsurance Price Return Index, available from LSEG Eikon. These data are sampled weekly and matched on dates with the catastrophe losses and CAT bond yields.

Table 1 shows the summary statistics of all the variables used in our analysis. Panel A reports the catastrophe variables. Duration counts the days between a disaster's official beginning and the end. It spans between a single day and 366 days, with an average slightly below a month. Unadjusted loss is the total economic cost of a loss for each recorded disaster. The average loss is around 6 billion U.S. dollars, but the distribution is skewed, with a maximum of 125 billion. CPI-adjusted loss is the economic cost of a loss adjusted for inflation using the consumer price index, resulting in slightly higher values than the unadjusted loss. The number of deaths ranges between zero, which happened in 101 recorded cases when only economic losses were materialized, and 2981 related to Hurricane Maria in September 2017. Out of 239 recorded disaster cases in our sample, there are 13 droughts, 24 floodings, one freeze, 145 severe storms, 33 tropical cyclones, 12 wildfires and 11 winter storms.

Panel B reports the CAT bond variables. All values are in percent per annum. Collateral yield is 1.28 percent on average, ranging from -0.01 to 5.51 percent depending on the U.S. monetary policy cycles. Insurance risk spread is more stable and less skewed, with an average of 5.83 percent and a standard deviation of 1.79 percent. Expected loss fluctuates in a relatively narrow interval between 1.05 and 2.47 percent, and 1.92 percent on average. The CAT bond market yield is the sum of the collateral yield and the insurance risk premium. It has a fairly centered distribution with a mean of 7.12 percent and a standard deviation of 3.01 percent. An alternative way to decompose it is to represent it as a sum of expected loss and the overall risk premium. Therefore, the average risk premium is around 5.2 percent per annum.

Panel C summarizes the capital and insurance market variables. The market excess return is 26 basis points per week on average. As expected, it is very volatile, evidenced by a considerable standard deviation of 230 basis points. The risk-free rate (here proxied by the 1-month U.S. Treasury yield) is two basis points on average. The Baa corporate bond spread is 2.39 percent per year, which is substantially lower than the insurance risk spread, indicating that typical CAT bonds are perceived to be riskier than the lowest investment-grade category of corporate bonds, consistent with the excess premium puzzle.

Table 1. Summary statistics of catastrophe, CAT bond, and capital and insurance market variables. The table shows the observations (Obs), mean, standard deviation (Std. Dev.), minimum, and maximum for catastrophe, CAT bond, and capital and insurance market variables. The data consists of weekly observations between October 8, 2010, and December 27, 2024.

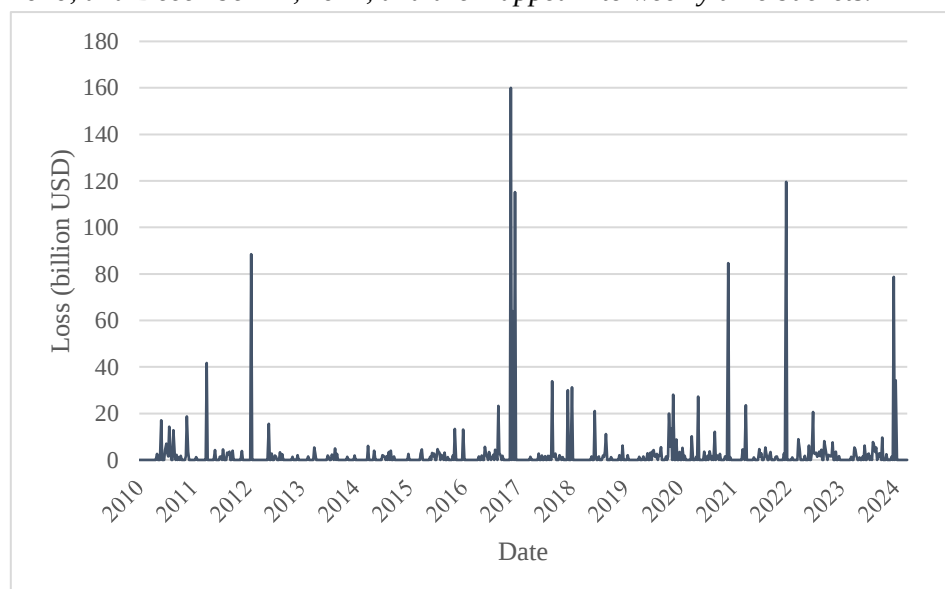
	Obs	Mean	Std. Dev.	Min	Max
Panel A: Catastrophe variables					
Duration (days)	239	29.43	79.21	1	366
Unadjusted loss (USD billion)	239	5.98	15.18	0.85	125.00
CPI-adjusted loss (USD billion)	239	7.20	18.23	1.06	160.00
Deaths	239	32.20	196.92	0	2981
Panel B: CAT bond variables					
Collateral yield	743	1.28	1.79	−0.01	5.51
Insurance risk spread	743	5.83	1.56	3.30	11.31
Expected loss	743	1.92	0.37	1.05	2.47
Market yield	743	7.12	3.01	3.67	15.91
Panel C: Capital and insurance market variables					
Market excess return	743	0.26	2.30	−14.56	12.34
Risk-free rate	743	0.02	0.04	0.00	0.12
Baa corporate bond spread	743	2.39	0.53	1.39	4.13
Reinsurance index return	743	0.21	2.95	−24.79	21.23

Sources: NOAA, Artemis, Kenneth French's Data Library, FRED, LSEG Eikon

Figure 1 illustrates the frequency and extent of catastrophe losses. It shows how CPI-adjusted economic losses associated with weather and climate disasters in the U.S. were distributed in time. The NOAA records losses when they occur, so we mapped them into weekly time buckets based on the initial date of a disaster. The losses were recorded only if they exceeded one billion dollars. Since disasters represent rare events, most weeks in the sample (524 out of 743) have no losses.

The economically most impactful events, with adjusted losses exceeding 50 billion U.S. dollars, are all associated with tropical cyclones. These are hurricanes Sandy (October 2012), Harvey (August 2017), Irma (September 2017), Maria (September 2017), Ida (August 2021), Ian (September 2022), and Helene (September 2024). The respective losses correspond to the most prominent peaks in Figure 1.

Figure 1. Frequency and extent of catastrophe losses. The graph illustrates CPI-adjusted economic losses associated with weather and climate disasters in the U.S., in billions of U.S. dollars. The data cover the period between October 8, 2010, and December 27, 2024, and are mapped into weekly time buckets.



Source: Author's calculations based on NOAA weather and climate disasters in the U.S.

Table 2. Catastrophe variables by disaster type. The table shows the average values of catastrophe duration (in days), unadjusted and CPI-adjusted loss (in billions of USD) and the number of deaths, broken down by disaster type. The sample period is between October 8, 2010, and December 27, 2024.

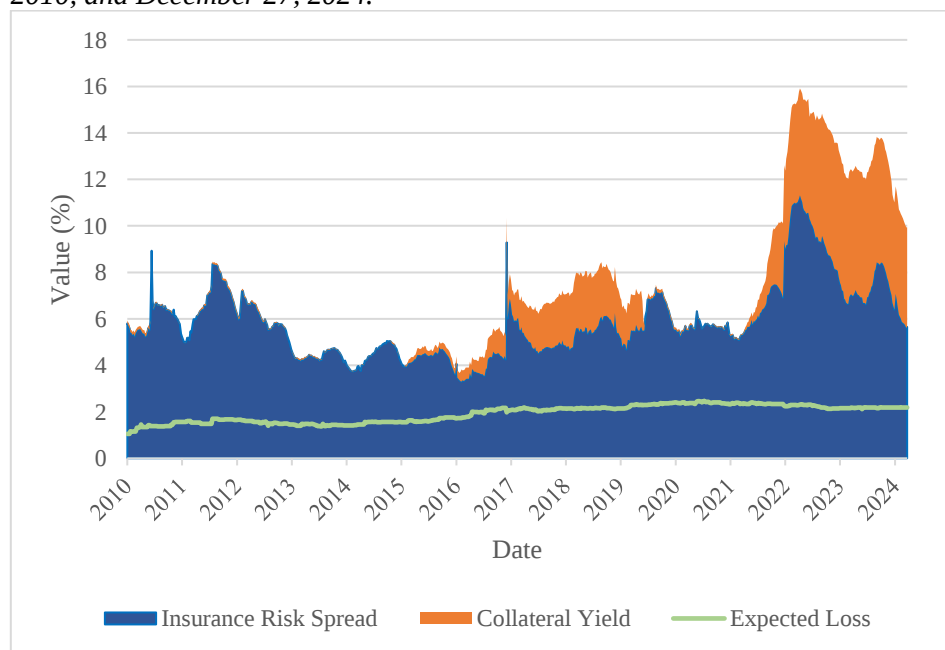
Disaster type	Duration (days)	Unadjusted loss (USD billion)	CPI-adjusted loss (USD billion)	Deaths
Drought	302.46	9.46	11.96	81.85
Flooding	20.21	2.76	3.46	10.79
Freeze	3.00	1.00	1.30	0.00
Severe storm	3.01	2.17	2.59	8.32
Tropical cyclone	3.67	23.74	28.32	129.09
Wildfire	167.17	7.73	9.46	31.83
Winter storm	4.55	4.32	5.14	47.73

Sources: NOAA

In general, tropical cyclones are the most devastating natural disasters in terms of deaths and economic losses. We can see this from Table 2, which shows the

average values of catastrophe duration, unadjusted and CPI-adjusted losses and the number of deaths by disaster type. On the other hand, they tend to last relatively short (less than four days on average). Disasters with a comparable duration, such as freezes and storms, have losses which are an order of magnitude smaller than those of tropical cyclones. However, winter storms have a very high average death toll. Floods last around three weeks on average and cause around ten deaths with moderately high economic losses. Wildfires and droughts are long-lasting, stretching for months on average. Their cumulative effect causes double-digit death tolls on average, with costs reaching tens of billions of dollars.

Figure 2. CAT bond data. The figure illustrates insurance risk spread, collateral yield and expected loss (all in percent) for the U.S. CAT bonds, calculated on a value-weighted basis. The insurance risk spread and the collateral yield are stacked areas, combining into the total market yield. The expected loss is displayed as a line. The data consists of weekly observations between October 8, 2010, and December 27, 2024.



Source: Artemis

Figure 2 displays the CAT bond data, showing insurance risk spread, collateral yield and expected loss. The insurance risk spread and the collateral yield are displayed as stacked areas, combining into the total market yield. The increases in insurance spread follow the catastrophic events leading to the most significant losses. This association is intuitive and aligns with Gürtler, Hibbeln, and

Winkelvos (2016), who find that disasters significantly impact CAT bond spreads. Section 3 will explore whether current CAT bond spreads also contain some predictive power for future catastrophe losses.

2. METHODOLOGY

To analyze the predictive power of CAT bond yields on catastrophe losses, we run the following regression:

$$\text{CATloss}_{t+h} = \beta_0 + \beta_1 \text{CATspread}_t + \beta_2 \text{MktRf}_t + \beta_3 \text{BaaSpread}_t + \beta_4 \text{ReinsIndex}_t + \beta_5 \text{CATloss}_t + \beta_6 \text{Week}_t + \varepsilon_{t+h}. \quad (1)$$

Here, CATloss_t is the total CPI-adjusted catastrophe loss during week t , and h is the forecast horizon, where we include horizons between one and eight weeks, 13 weeks, 26 weeks, 39 weeks and 52 weeks. Our primary explanatory variable is CATspread_t , representing the insurance risk spread of CAT bonds in week t .

We follow previous studies and include the weekly excess return on the market portfolio, MktRf_t , and the Baa corporate bond spread, BaaSpread_t , to control for the impact of financial markets. We also include the reinsurance index return, ReinsIndex_t , to control for the global trends in the reinsurance market. The rationale is similar to the one given by Zhao & Yu (2020): capital-market variables capture the influence of financial markets on the predictive ability of CAT bond yields for actual catastrophe losses in future periods, while fluctuations in the reinsurance index highly correlate with future catastrophe losses. We also include catastrophe loss in week t as an additional regressor in Equation (1) to control for the influence of ongoing events on the predictive ability of CAT bond spreads. The idea is to rule out the scenario that any predictive ability of CAT bond spreads originates from their relationship with current catastrophe event variables rather than actual future losses.

Finally, we control for seasonal effects of weather and climate disasters by including the variable Week_t , which enumerates the calendar week in a given year. This variable should pick up any potential regularities in weather patterns that may occur in specific periods of the year. As an illustration, the average value of this variable, conditionally on any catastrophe loss in our sample, is around 23 (beginning of June). The losses above 50 billion USD occur on average in week 38 (mid-September).

We do not observe catastrophe losses continuously. However, we observe them only during disasters, so most CATloss observations will be zero.⁸⁶ Thus, our dependent variable is left-censored, so we estimate the regression coefficients in Equation (1) using the Tobit model. We assume that the error term ε_{t+h} satisfies the usual assumptions.

3. RESULTS

Tables 3–5 show the results obtained from Tobit regression, given by Equation (1). They report regression coefficients, standard errors, significance levels, the number of observations used in each regression given the forecast horizon, and the likelihood ratio test statistic for joint significance of explanatory variables.⁸⁷ We track the ability of CAT bond spreads to predict future catastrophe losses across different forecast horizons h . Table 3 shows the results for $h = 1, 2, 3$ and 4. Table 4 shows the results for $h = 5, 6, 7$ and 8. Table 5 shows the results for $h = 13, 26, 39$ and 52, approximately corresponding to three, six, nine and twelve months.

The results indicate that CAT bond spreads weakly predict future catastrophe losses at relatively lower forecast horizons. The CATspread _{t} coefficients are statistically significant at the 5% level for $h = 1$ and 2, and at the 10% level for $h = 3, 5$ and 6. The point estimates of significant coefficients are all positive, having values that range between 1.22 and 1.62. These values imply that, for instance, a percentage point increase in CAT bond spreads today is associated with a 1.62 billion dollar increase in catastrophe losses two weeks from now.

As expected, the ability of CAT bond spreads to predict future losses deteriorates with forecast horizon. The CATspread _{t} coefficients become insignificant at all reasonable levels beyond six weeks ahead. The joint significance of all regressors is preserved at a 5% level up to 39 weeks ahead, but falls at horizons of the order of one year.

⁸⁶ There are 524 out of 743 observations where the value of CATloss is zero, around 70% of the sample.

⁸⁷ The test statistic is distributed as chi-squared with six degrees of freedom.

Table 3. Regression results for the predictive ability of CAT bond spreads. This table shows coefficients from Tobit regression, given by Equation (1), obtained with weekly observations between October 8, 2010, and December 27, 2024. The dependent variable is catastrophe loss in week $t + h$ ($CATloss_{t+h}$), where h is the forecasting horizon, i.e., the number of weeks ahead of the current date t . Here, we use the forecasting horizons of 1, 2, 3 and 4 weeks. The independent variables are the CAT bond insurance risk spread ($CATspread_t$), the excess return on the market portfolio ($MktRf_t$), the spread of Baa corporate bonds over 10-year U.S. Treasury Notes ($BaaSpread_t$), the return on the FR Global Reinsurance Price Return Index ($ReinsIndex_t$), catastrophe loss in week t ($CATloss_t$) and the calendar week in a given year ($Week_t$). We report the regression coefficients, the number of observations N and the likelihood ratio (LR) test statistic for joint significance of explanatory variables. Numbers in parentheses are the standard errors. The asterisks indicate the usual significance levels: *** for significance at 1%; ** for significance at 5%; * for significance at 10%.

CATloss _{t+h}	Forecast horizon h (weeks):			
	1	2	3	4
constant	-11.30 (7.45)	-14.77** (7.26)	-9.76 (7.49)	-7.25 (7.29)
CATspread _t	1.42** (0.69)	1.62** (0.67)	1.35* (0.69)	0.99 (0.67)
MktRf _t	0.24 (0.63)	0.12 (0.61)	0.63 (0.62)	-0.94 (0.60)
BaaSpread _t	-3.52* (2.12)	-2.46 (2.07)	-3.32 (2.13)	-2.89 (2.09)
ReinsIndex _t	-0.67 (0.50)	-0.30 (0.45)	-0.69 (0.48)	0.63 (0.45)
CATloss _t	-0.21 (0.16)	0.32*** (0.08)	-0.23 (0.17)	0.29*** (0.09)
Week _t	-0.16** (0.08)	-0.20*** (0.08)	-0.23*** (0.08)	-0.31*** (0.08)
N	742	741	740	739
LR	17.33***	32.35***	21.32***	34.50***

Source: Author's calculations based on NOAA, Artemis, Kenneth French's Data Library, FRED and LSEG Eikon data.

Table 4. Regression results for the predictive ability of CAT bond spreads. This table shows coefficients from Tobit regression, given by Equation (1), obtained with weekly observations between October 8, 2010, and December 27, 2024. The dependent variable is catastrophe loss in week $t + h$ ($CATloss_{t+h}$), where h is the forecasting horizon, i.e., the number of weeks ahead of the current date t . Here, we use the forecasting horizons of 5, 6, 7 and 8 weeks. The independent variables are the CAT bond insurance risk spread ($CATspread_t$), the excess return on the market portfolio ($MktRf_t$), the spread of Baa corporate bonds over 10-year U.S. Treasury Notes ($BaaSpread_t$), the return on the FR Global Reinsurance Price Return Index ($ReinsIndex_t$), catastrophe loss in week t ($CATloss_t$) and the calendar week in a given year ($Week_t$). We report the regression coefficients, the number of observations N and the likelihood ratio (LR) test statistic for joint significance of explanatory variables. Numbers in parentheses are the standard errors. The asterisks indicate the usual significance levels: *** for significance at 1%; ** for significance at 5%; * for significance at 10%.

CATloss _{t+h}	Forecast horizon h (weeks):			
	5	6	7	8
constant	-6.28 (7.45)	-6.34 (7.47)	-3.11 (7.47)	-2.12 (7.49)
CATspread _t	1.32* (0.69)	1.22* (0.69)	1.09 (0.69)	0.91 (0.69)
MktRf _t	0.19 (0.63)	0.01 (0.63)	-0.15 (0.63)	1.14* (0.64)
BaaSpread _t	-3.56* (2.15)	-3.46 (2.16)	-3.77* (2.17)	-3.73* (2.17)
ReinsIndex _t	-0.45 (0.46)	-0.27 (0.48)	0.08 (0.48)	-0.14 (0.47)
CATloss _t	-0.34 (0.23)	-0.09 (0.12)	-0.32 (0.22)	-0.17 (0.16)
Week _t	-0.33*** (0.08)	-0.33*** (0.08)	-0.38*** (0.08)	-0.41*** (0.08)
N	738	737	736	735
LR	32.36***	28.31***	37.40***	42.46***

Source: Author's calculations based on NOAA, Artemis, Kenneth French's Data Library, FRED and LSEG Eikon data.

Table 5. Regression results for the predictive ability of CAT bond spreads. This table shows coefficients from Tobit regression, given by Equation (1), obtained with weekly observations between October 8, 2010, and December 27, 2024. The dependent variable is catastrophe loss in week $t + h$ ($CATloss_{t+h}$), where h is the forecasting horizon, i.e., the number of weeks ahead of the current date t . Here, we use the forecasting horizons of 13, 26, 39 and 52 weeks. The independent variables are the CAT bond insurance risk spread ($CATspread_t$), the excess return on the market portfolio ($MktRf_t$), the spread of Baa corporate bonds over 10-year U.S. Treasury Notes ($BaaSpread_t$), the return on the FR Global Reinsurance Price Return Index ($ReinsIndex_t$), catastrophe loss in week t ($CATloss_t$) and the calendar week in a given year ($Week_t$). We report the regression coefficients, the number of observations N and the likelihood ratio (LR) test statistic for joint significance of explanatory variables. Numbers in parentheses are the standard errors. The asterisks indicate the usual significance levels: *** for significance at 1%; ** for significance at 5%; * for significance at 10%.

CATloss _{t+h}	Forecast horizon h (weeks):			
	13	26	39	52
constant	-5.55 (7.43)	-12.98 (7.90)	-23.41*** (8.18)	-4.56 (8.26)
CATspread _t	0.87 (0.68)	0.13 (0.70)	0.77 (0.73)	0.58 (0.75)
MktRf _t	-0.34 (0.62)	-0.14 (0.64)	0.34 (0.64)	-0.34 (0.67)
BaaSpread _t	-2.84 (2.18)	-4.45* (2.27)	-3.50 (2.36)	-3.91 (2.50)
ReinsIndex _t	0.29 (0.49)	0.22 (0.53)	-0.27 (0.51)	0.23 (0.51)
CATloss _t	0.00 (0.11)	0.03 (0.10)	0.02 (0.10)	-0.08 (0.14)
Week _t	-0.33*** (0.07)	0.25*** (0.08)	0.40*** (0.08)	-0.22*** (0.08)
N	730	717	704	691
LR	27.36***	15.86**	30.02***	11.19*

Source: Author's calculations based on NOAA, Artemis, Kenneth French's Data Library, FRED and LSEG Eikon data.

The spread of Baa corporate bonds over 10-year U.S. Treasury Notes is occasionally significant at the 10% level, with a negative coefficient. An increase of one percentage point in corporate bond spread is associated with a decrease of future catastrophe losses by approximately 3.5–4.5 billion dollars. A potential interpretation of this relationship is that disaster losses are mitigated better when the perception of overall corporate risk is higher. However, the effect is not robust enough to infer some meaningful practical or policy implications.

Including contemporaneous catastrophe losses as an additional control improved the regression, as the coefficient is significant for some horizons. In these cases, it takes positive values, showing that losses exhibit mild persistency over closer periods (two to four weeks).

The only robust predictor among the explanatory variables considered in this analysis is the seasonal variable. The week-of-the-year counter remains highly significant at all forecast horizons, implying that seasonal effects have the most persistent predictive ability for losses induced by weather and climate disasters. This finding confirms our intuition about the dominant relevance of geophysical phenomena to weather and climate disasters.

* * *

This chapter analyzed whether CAT bond yields can predict future catastrophe losses arising from weather and climate disasters. The evidence from the U.S. weekly data between October 8, 2010, and December 27, 2024, suggests that the CAT bond insurance risk spread has a moderate predictive ability up to six weeks ahead. Therefore, the information that the CAT bond market aggregates contains some degree of predictability of the triggering events. CAT bond prices thus factor in the likelihood of natural disasters. The predictability does not come from anticipation of seasonal effects related to weather phenomena, which are controlled for in our regressions.

Our results indicate multiple avenues for future research on this topic, which may have various practical and policy implications. From a practical standpoint, the ability of CAT bond markets to aggregate and reflect short-term catastrophe risk has value for insurers, reinsurers and investors. Market signals derived from CAT bond spreads may serve as supplementary indicators in underwriting, pricing and portfolio management decisions. Moreover, given the short-term predictive horizon, relevant stakeholders, including public agencies and risk managers, could integrate these signals into operational disaster preparedness strategies. From a policy perspective, our findings support recognizing insurance-linked securities markets as valuable contributors to the broader risk monitoring

infrastructure. Regulators and policymakers may promote transparency and liquidity in CAT bond markets to enhance informational efficiency. Furthermore, incorporating market-based indicators into supervisory frameworks could strengthen early warning systems for climate-related financial risks. As climate disasters become increasingly frequent and severe, leveraging financial market data for timely insights may aid financial stability and public resilience efforts.

ACKNOWLEDGEMENT

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Chapter 5.

SUSTAINABLE AGRICULTURE IN THE DIGITAL AGE: INNOVATIONS IN INSURANCE

Sustainable agriculture acts as a crucial pillar of global development, supporting economic stability and resource conservation. Advances in data collection, remote sensing, and machine learning enabled policymakers to make more informed and timely decisions in sustainable farming systems. Furthermore, data driven approach has opened new opportunities for forecasting agriculture outcomes, and ultimately, for transforming agriculture insurance practices. By leveraging Big Data and advanced analytics, insurers can now more precisely estimate risk, reduce uncertainty, and form instruments tailored to farmers' needs in changing climate.

The chapter aims to examine how digital innovations in agriculture, particularly a machine learning-based insurance model, can deliver effective insurance solutions and enhance climate resilience in developing countries like Serbia. Furthermore, it explores the contribution of agriculture to sustainable development by examining key global trends and underlining agriculture's vulnerability to climate change, particularly in developing countries like Serbia, where rising temperatures threaten GDP and productivity. It also highlights the increasing role of digitalization in modernizing agricultural practices and improving food security. Against this backdrop, the study presents a novel machine learning-based model for calculating agricultural insurance premiums using historical climate and agricultural data. The model integrates climate variability indicators and actuarial principles to calculate expected losses more accurately. Serving as a data-driven decision support tool, it aims to enhance risk assessment and promote sustainable, resilient insurance solutions in Serbia's agricultural sector.

1. THE CONTRIBUTION OF AGRICULTURE TO SUSTAINABLE DEVELOPMENT

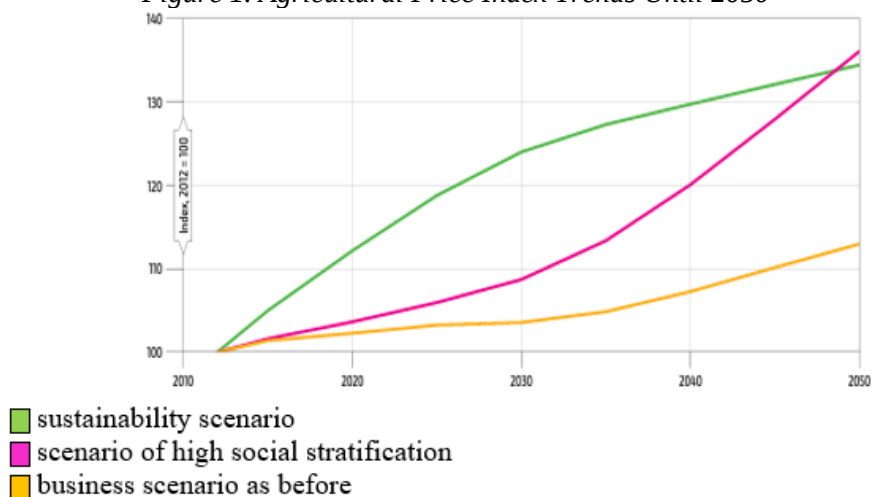
Climate conditions are undergoing significant changes, while intensive agricultural and livestock production continues to provide food for the global population. However, this process can lead to the partial destruction of natural habitats, disruption of biodiversity, and deterioration of water quality, among other environmental concerns. The Sustainable Development Goals (SDGs)

present an opportunity to enhance and promote the advancement of the agricultural sector.

Both crop and livestock production are increasingly exposed to various risks due to the growing frequency of extreme weather events, climate change, and the emergence of new animal diseases. These factors drive the need for agricultural insurance as a mechanism for economic protection against diverse agrarian risks. At the microeconomic level, insurance provides financial security to agricultural producers, ensuring resilience, continuity, and competitiveness while fostering long-term development potential.

The climate crisis exacerbates the global food crisis. An unsustainable food system worsens the issue due to significant losses during transportation and storage, as well as the waste of unused food. Addressing food scarcity in the future requires action in several key areas: raising consumer awareness to discourage food waste, strengthening legal regulations, and implementing more efficient pricing policies that incorporate the environmental costs associated with biodiversity loss. Countries with high living standards should strive for balanced food consumption patterns and the advancement of international food trade to mitigate food deficits.

Figure 1. Agricultural Price Index Trends Until 2050

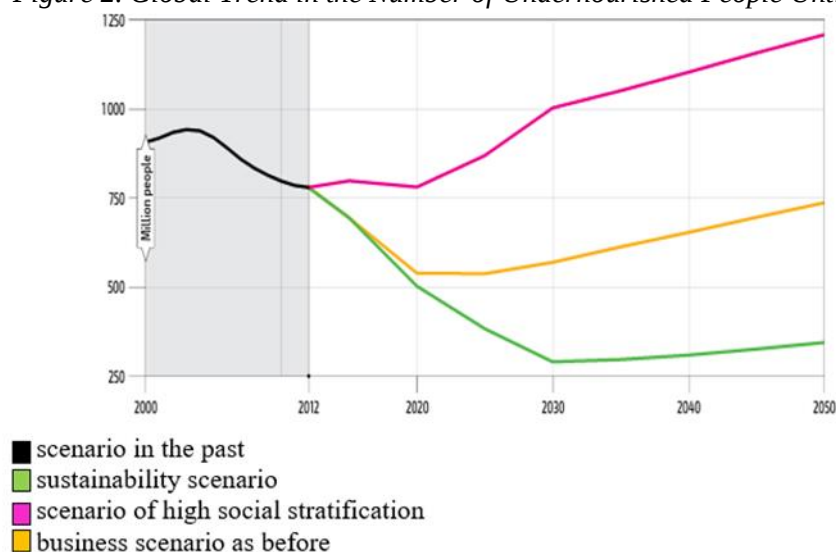


Source: Food and Agriculture Organization of the United Nations (2018). *The future of food and agriculture. Alternative pathways to 2050*. Rome: FAO, p. 100, https://knowledge4policy.ec.europa.eu/publication/future-food-agriculture-alternative-pathways-2050_en

Figure 1 presents the projected agricultural price index, indicating expected changes in agricultural product prices and forecasting market trends for agricultural commodities. The base year for comparison is 2012.

Figure 2 illustrates the dynamics of the global number of undernourished people, showing trends in food insecurity over time. The base year for reference is 2012.

Figure 2. Global Trend in the Number of Undernourished People Until 2050



Source: Food and Agriculture Organization of the United Nations (2018), *op. cit.*, p. 100.

Companies will face a decline in worker productivity as a consequence of heatwaves. Given the pronounced trend of population aging, this issue is expected to become more significant. In 1995, rising temperatures in the agricultural sector resulted in a loss of 0.04% of total working hours, equivalent to 25,200 lost labor hours. Projections indicate that by 2030, the lost working hours will increase to 0.09%, amounting to 56,700 hours. Table 1 presents the decline in labor productivity across various sectors in Serbia.

Due to rising temperatures and declining productivity in enterprises, Serbia's GDP is expected to experience significant changes. Projections indicate a GDP reduction of \$171 million by 2040. Additionally, with a minimum temperature increase of 1°C, Serbia's GDP could decline by \$1.097 billion by the end of the

century. In a more severe scenario, with a 4°C temperature rise, the GDP loss could reach \$6.261 billion.⁸⁸

Table 1. Decline in Productivity (Lost Working Hours) Across Different Sectors in Serbia: A Comparative Analysis for 1995 and 2030

Sector	1995	2030
Agriculture (Shaded) (%)	0.04	0.09
Industry (%)	0.01	0.03
Construction (Shaded) (%)	0.04	0.09
Services (%)	0	0
Total (%)	0.01	0.03
Total (in thousand work hours)	0.4	1

Source: Mitrović & Božanić (2019), op. cit., p. 24.

In alignment with the Paris Agreement, Serbia has adopted the Climate Change Strategy with an Action Plan, establishing a comprehensive national policy framework aimed at reducing greenhouse gas emissions and enhancing climate resilience. Agriculture is among the most vulnerable sectors, facing land degradation, reduced ecosystem productivity, and increased frequency of extreme weather events^{89 90}. These effects disproportionately impact developing countries, which have contributed the least to global emissions.

Intensive agriculture, relying on fossil fuel combustion and extensive legume cultivation, has significantly disrupted the nitrogen cycle, resulting in ecosystem imbalances, eutrophication, and nitrous oxide emissions—a potent greenhouse gas. In response, companies such as Nestlé are adopting regenerative agriculture, engaging over 600,000 farmers to promote sustainable, deforestation-free supply chains and ecosystem restoration⁹¹.

⁸⁸ Mitrović, Đ., & Božanić, D. (2019). *Studija o socio-ekonomskim aspektima klimatskih promena u Republici Srbiji*, p. 25. Retrieved from <https://www.klimatskepromene.rs/dokumenta/studija-o-socio-ekonomskim-aspektima-klimatskih-promena-u-republici-srbiji/>

⁸⁹ Mirković, V., & Lukić, J. (2018). Energy Transition in the EU and Serbia: Strategic Approach to Climate Change. *Economic Perspectives*, 23(3-4), pp. 229-230.

⁹⁰ Mihailović, B. M., Radosavljević, K., Popović, V., & Puškarić, A. (2024). Impact of digital marketing on the performance of companies in the agricultural sector of Serbia. *Ekonomika poljoprivrede*, 71(1), pp. 173-188.

⁹¹ Creating Shared Value Sustainability Report, 2022, p. 5. Nestle company report. 2020. 2020 – annual – review – en, Retrieved from 2024-annual-review-en.pdf (nestle.com)

Emerging trends emphasize the role of digitalization and ICT, biotechnology, and nanotechnology in enhancing productivity and sustainability in agriculture⁹². The Internet of Things (IoT) plays a pivotal role in precision agriculture by enabling remote monitoring of soil, crops, and water usage, thus supporting data-driven decision-making. IoT systems further facilitate livestock management and pest control, both of which are increasingly challenged by climate variability⁹³.

Cloud computing and Big Data analytics allow for the efficient processing of large datasets to identify sustainability patterns, optimize energy use, and mitigate environmental impacts⁹⁴. Predictive analytics, driven by these technologies, contribute to enhanced production planning and risk reduction⁹⁵. To mitigate climate-related risks, companies are encouraged to implement risk assessment, supply chain diversification, resource optimization, investments in resilient infrastructure, and the promotion of sustainable business models^{96 97}.

As an example of digital innovation, the BioSens Institute developed the DDOR TERRA platform for rapid damage reporting in agriculture. Furthermore, robotics and autonomous systems, such as drones and driverless tractors, are transforming agricultural operations, although adoption barriers remain due to limited technological acceptance among farmers.

2. THE DIGITALIZATION OF AGRICULTURE

In the context of sustainable development, agriculture faces the challenge of how to provide enough food for a growing population while preserving natural resources and the environment. Digitization in agriculture appears as a key tool

⁹² Paraušić, V., & Nikolić Roljević, S. (2021). *The Role of Innovations in the Agricultural Sector in Achieving Serbia's Sustainable Development Goals*. Belgrade: Institute for Agricultural Economics, p. 18.

⁹³ Čelik, P. (2020). *Digital Transformation of Business and Its Security Implications*. Novi Sad: Faculty of Economics and Engineering Management, pp. 95-96.

⁹⁴ Zečević, A., & Radosavljević, K. (2014). Web-based business applications as the support for increased competitiveness in agribusiness. *Ekonomika preduzeća*, 62(7-8), pp. 405-418.

⁹⁵ <http://m.srja.cropprotection.net/news/smart-farming-iot-is-transforming-the-future-42791147.html>

⁹⁶ De Mauro, A., Greco, M., & Grimaldi, M. (2019). Understanding big data through a systematic literature review: the ITMI model. *International Journal of Information Technology & Decision Making*, 18(04), pp. 1433-1461.

⁹⁷ Kostić, M. (2021). *Precision Agriculture*. Novi Sad: University of Novi Sad, Agricultural Faculty, p. 18.

for solving that challenge, as it introduces advanced technologies for more efficient and environmentally responsible production management. Digital transformation of the agricultural sector thus becomes a bridge between the principles of sustainable development and modern technological solutions, including the application of artificial intelligence on farms. Key areas of application of digital technologies in agriculture include precise soil analytics, irrigation optimization and rational application of pesticides and fertilizers. Thanks to sensors, GPS navigation and satellite observation, farmers can monitor soil properties such as moisture, pH value and nutrient content in detail, and make precise sowing and fertilization plans according to the actual crop needs. At the same time, the application of smart irrigation systems based on the Internet of Things (IoT) ensures optimal use of water, so that plants are watered at the right time and with exactly the amount of water they need. This resource optimization reduces waste and increases the resilience of agriculture to drought and climate change. Digital innovations also contribute to a more sustainable use of agrochemicals through a more rational use of pesticides and mineral fertilizers. Drones and digital systems for crop surveillance make it possible to detect pests or plant diseases early and allow for targeted application of protective agents only where necessary, instead of broad preventive application across entire fields. Such an approach not only reduces costs and negative impact on the ecosystem, but also preserves soil quality in the long term. In this way, the digitization of agriculture lays the foundations for sustainable agricultural development, while at the same time opening the door to specific application of artificial intelligence in the following chapters. For the aforementioned reasons, we analyze the specific contribution of the application of advanced technologies in the agricultural sector, with a special focus on precise analytics, optimization of the irrigation process and rational use of pesticides and fertilizers. The review will include current global trends, European practices and Serbian examples, all in order to show how digital transformation contributes to the achievement of sustainable development goals in the agricultural sector.

Precise soil analytics

Precise soil management begins with detailed analytics. It includes monitoring the chemical composition, structure and moisture content of the soil in real time. Networked IoT sensors in the field today record parameters such as moisture, temperature, pH and nutrient content, while AI algorithms turn that data into recommendations for agronomists. That way, farmers get information about when and how much fertilizer to add, or whether the soil is wet enough for seeding, instead of relying on field-wide averages. Studies emphasize that lower

use of fertilizers and higher soil fertility are the key benefits of this approach⁹⁸. By supplementing historical soil data with data on weather conditions, artificial intelligence can predict optimal times for planting and harvesting cultivated crops. In this way, it is possible to predict which climatic conditions and soil moisture bring the least risk of crop failure.

An example of the use of advanced technology in this area is shown in research published in *Nature Food*. Scientists have developed a soil ammonium sensor (called chemPEGS) that, with the help of artificial intelligence algorithms, combines multiple factors such as weather data, pH value, soil conductivity and time since previous fertilization. The goal is to predict the total nitrogen in the soil and establish the optimal time for the next crop feeding⁹⁹. This system helps farmers precisely establish the amount and timing of fertilization, which maximizes nutrient utilization by plants and prevents overfertilization that leads to pollution. Data shows that the excessive use of fertilizers has so far rendered infertile about 12% of the once arable land in the world, and the consumption of nitrogen fertilizers has increased by 600% in the last 50 years³.

The European Union's projects and institutions actively research and apply the approach of precise soil analysis. A number of digital agronomy platforms have been developed to help farmers make the most optimal decisions. The BioSense Institute in Serbia applies various technologies in agriculture. They have developed an advanced system for autonomous soil sampling and analysis called Agrobot Lala¹⁰⁰. It is an automated system that moves over cultivated areas and takes soil samples. The goal is to measure nitrate content in real time with the help of ion-selective probes¹⁰¹.

Each sample is analyzed individually depending on the geographical location, which is a big shift compared to traditional systems that take into account the

⁹⁸ Sharma, A., Sharma, A., Tselykh, A., Bozhenyuk, A., Choudhury, T., Alomar, M. A., & Sánchez-Chero, M. (2023). Artificial intelligence and internet of things oriented sustainable precision farming: Towards modern agriculture. *Open Life Sciences*, 18(1), 20220713.

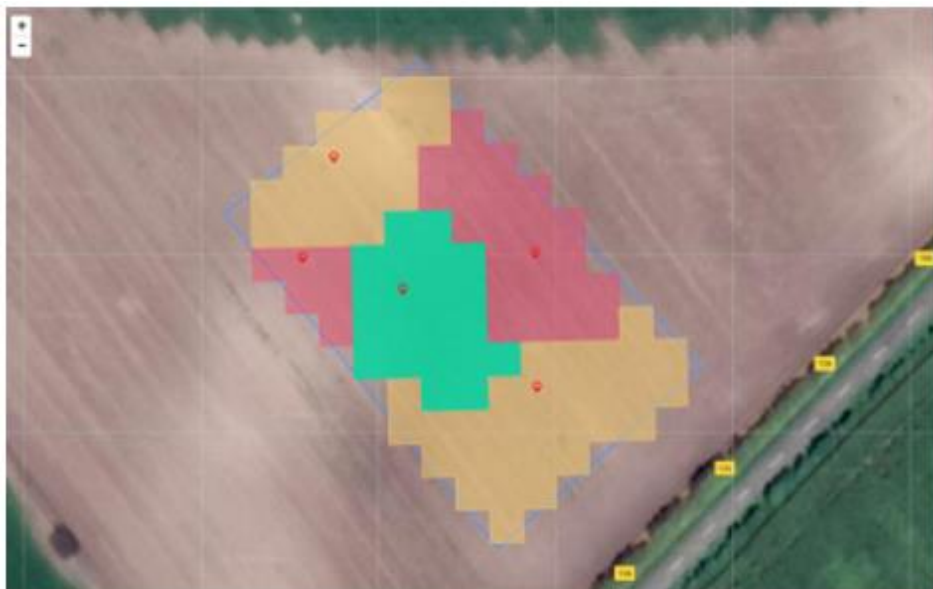
⁹⁹ Imperial College London (2021). Low-cost AI soil sensors could help farmers curb fertilizer use. *Phys.org*. Retrieved March 19, 2025, from <https://phys.org/news/2021-12-low-cost-ai-soil-sensors-farmers.html>

¹⁰⁰ Agrobot for in-field soil analysis. (n.d.). *BioSense Institute*. Retrieved March 28, 2025, from <https://biosens.rs/en/themes/agrobot-2>

¹⁰¹ Kitić, G., Krklješ, D., Panić, M., Petes, C., Birgermajer, S., & Crnojević, V. (2022). Agrobot Lala—an autonomous robotic system for real-time, in-field soil sampling, and analysis of nitrates. *Sensors*, 22(11), 4207.

average multi-site sample. The result of such a detailed analysis are precise fertility maps based on which the user can apply fertilizer in a targeted manner, as Figure 3 shows. This system optimizes the soil fertilization process and enables sustainable production.

Figure 3. Sampling zones and points generated by Robot Lala



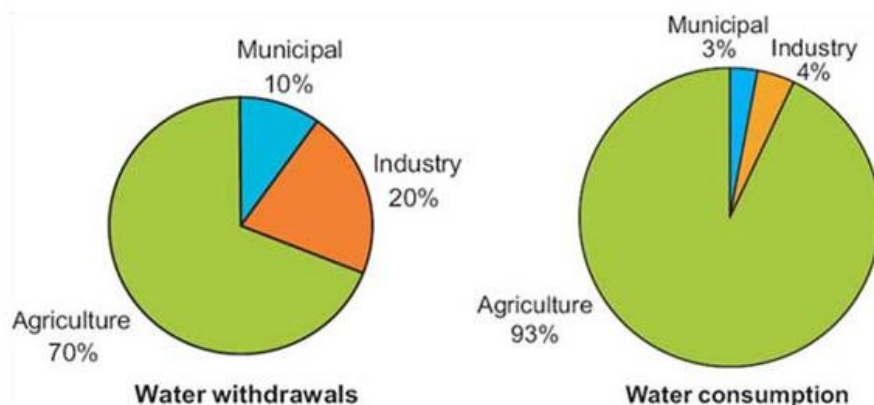
Source: Kitić et al. (2022), op. cit., p. 4.

Optimization of irrigation

Water is a key resource in agriculture. However, traditional irrigation systems very often lead to its excessive use. Globally, agriculture uses about 70% of available drinking water¹⁰², and excess water can lead to soil erosion and leaching. Therefore, optimization with the help of artificial intelligence can be a significant solution to the problem of suboptimal soil irrigation. Figure 4 shows FAO data on shares of water withdrawal and consumption by sector. Water withdrawal refers to the amount of water taken from natural sources, regardless of whether or not the water will be returned. On the other hand, consumption represents the permanent loss of water that is lost or retained in the system.

¹⁰² <https://www.fao.org/4/y5582e/y5582e04.htm>

Figure 4. Share of global water withdrawals and consumption by sector



Source: Food and Agriculture Organization of the United Nations (2004). *The role of water in agricultural development*. Rome: FAO, <https://www.fao.org/4/y5582e/y5582e04.htm>

AI systems enable precise management of soil irrigation based on weather data and overall soil condition. For example, predictive analytics and machine learning models can adjust watering schedules based on soil moisture, weather forecast and crop development stage. Also, developed sensor networks can take into account additional information about a specific crop or soil type so that irrigation can be automatically started or stopped in order to maintain the optimal level of moisture.

Research shows that the application of AI tools in the irrigation process leads to significantly more efficient use of water in the irrigation process. Analysis of studies has shown that systems based on artificial intelligence achieve an average increase in water use efficiency of 30 to 40% compared to traditional methods¹⁰³. The same study states that under controlled conditions, water consumption was reduced by about 88% thanks to an artificial intelligence system that maintained soil moisture levels. Also, these systems minimize the degree of soil degradation caused by inadequate irrigation.

In Europe, special focus is on precision irrigation. Many European farms are already using sensor networks and satellite monitoring. An example is the

¹⁰³ Oğuztürk, E., Murat, C., Yurtseven, M., & Oğuztürk, T. (2025). The effects of AI-supported autonomous irrigation systems on water efficiency and plant quality: A case study of *Geranium psilostemon* Ledeb. *Plants*, 14(5), 770.

AgriBIT project. A large number of services have been developed that integrate satellite data and sensors in order to effectively monitor crop status and soil moisture in real time through a mobile application¹⁰⁴. Such systems can bring flexibility when planning irrigation. In Serbia, irrigation is insufficiently developed and it is estimated that only 8.3% of arable land is irrigated. However, this may mean that there is huge room for improvement in this field. BioSense institute initiatives have included satellite detection of irrigation problems. The cooperation of the European Union and FAO resulted in the installation of automatic meteorological stations for moisture monitoring in Serbia. It is expected that the wider application of such technologies will contribute to the development of agriculture at the level of the entire country.

Correct dosing of pesticides and fertilizers

The application of pesticides and mineral fertilizers is an area where precision agriculture brings direct environmental benefits. The traditional spraying approach often involves the application of preparations over the entire soil surface, which leads to wastage and irrational consumption of fertilizers¹⁰⁵. Artificial intelligence tools have the potential to change this with the help of computer vision and machine learning. Drones or machines equipped with cameras recognize weeds, pests or signs of crop disease, so chemicals are applied only where they are really needed. For example, modern “spot-spraying” sprayers use high-resolution cameras and AI algorithms that can recognize each weed between crop rows in a fraction of a second and activate the spray directly above the spotted weed, instead of continuously spraying the entire field. This can drastically reduce the amount of herbicide used. Field tests on soybeans in Iowa (USA) showed savings of 76% in the use of herbicides on average (from 43% to even 91% per individual field), without losing the effectiveness of weed control¹⁰⁶. Similarly, experts report that AI targeted spraying systems have helped farmers reduce overall pesticide use by up to 90% in some cases¹⁰⁷. Such a significant reduction in chemicals not only reduces costs for farmers, but also has great environmental significance such as reducing water and soil pollution,

¹⁰⁴ <https://cordis.europa.eu/article/id/454267-improving-europe-s-precision-agriculture-with-ai>

¹⁰⁵ Richards, A. (2024). The Environmental Impact of Precision Spraying: Reducing Chemical Use and Protecting Ecosystems. *AgTechLogic*. Retrieved March 15, 2025, from <https://agtechlogic.com/the-environmental-impact-of-precision-spraying-reducing-chemical-use-and-protecting-ecosystems/>

¹⁰⁶ <https://growiwm.org/herbicide-savings-from-precision-spraying-technology/>

¹⁰⁷ <https://agresearch.okstate.edu/news/articles/2024/scientists-use-ai-to-reduce-ag-costs-and-labor.html>

saving beneficial insects (pollinators, pest predators) and slowing down the emergence of harmful organisms.

Scientific literature confirms these trends. The European Parliament's analysis states that precision methods can lead to a 20-30% reduction in pesticide use, as well as up to 50-80% less pesticide-treated area (owing to targeted application instead of treating every hectare)¹⁰⁸. This protects ecosystems and biodiversity on and around agricultural land. Fewer chemicals in the fields means preservation of the population of bees and other pollinators, as well as richer microbiological life in the soil itself. In addition, precise variable fertilization (with the help of VRT (variable rate technology) allows mineral fertilizers to be applied only where soil analyses show a nutrient deficit, thereby reducing the total amount of nitrogen and phosphorus input.

In Europe, these techniques are the focus of sustainable agriculture strategies. Through the "Farm to Fork" strategy, the EU set the goal of reducing the use of chemical pesticides by 50% by 2030¹⁰⁹. Achieving that ambitious goal relies heavily on the wider application of precision spraying and integrated pest management (IPM). Examples of good practice already exist: European producers and researchers have developed systems that combine satellite imagery for the early detection of diseases and pest attacks with drones that carry out targeted spraying only on vulnerable parts of plots.

Serbia follows these trends as well. Larger farms have started using drones to spray orchards and GPS-guided sprayers with sector control (turning off nozzles on already treated zones). However, experts point out that the adoption of precision agriculture in Serbia is only in its infancy among small farms, mainly due to costs and lack of information¹¹⁰. Projects such as the EU H2020 DRAGON educate farmers on the cost-effectiveness of precision methods and have demonstrated successful case studies, from space-based crop monitoring to pest risk assessment models¹¹¹.

¹⁰⁸ <https://croplifeeurope.eu/farmers-toolbox/digital-and-precision-agriculture/>

¹⁰⁹ European Commission (2023). Using Less Chemical Pesticides: European Commission Publishes Toolbox of Good Practices. *News Article*, Retrieved March 27, 2025, from https://agriculture.ec.europa.eu/media/news/using-less-chemical-pesticides-european-commission-publishes-toolbox-good-practices-2023-02-28_en

¹¹⁰ <https://www.acdivoca.org/2024/02/making-agriculture-smarter-in-serbia-through-precision-farming/>

¹¹¹ <https://cordis.europa.eu/article/id/435491-lighting-a-beacon-for-precision-farming-knowledge-in-serbia>

However, despite all the advantages that artificial intelligence and digitization bring, risks in agriculture cannot be completely eliminated. Extreme climatic events, plant diseases and other unforeseen circumstances can still significantly threaten yields, regardless of the level of technology application. That is why, in addition to technological solutions, the development of modern insurance systems in agriculture plays a key role in ensuring the long-term stability and safety of food production.

3. INNOVATIONS IN AGRICULTURE INSURANCE

Agriculture production has proved to be highly risky venture. The uncertainty of future prices and yields impedes farmers' long-term capital planning and short-term production resolutions. As probability of default is relatively high, financial institutions are unwilling to approve loans to farmers, ultimately reducing farm profits in the long term. Due to the substantial systematic component present in a portfolio of agriculture risks, insurance markets are often unable to conduct affordable risk management mechanism for agriculture production. As a result, many governments subsidize insurance companies and/or farmers in form of price-support programs, tax breaks, subsidized reinsurances, etc. However, government programs seldom provide expected results and come at a high social cost.¹¹²

In the face of extreme weather events and climate change, the implementation of advanced technologies and tools has transfigured the agriculture insurance sector, enabling more precise, effective and efficient resolutions for both insurers and producers. Artificial Intelligence (AI) and blockchain-based contracts have proved to enhance insurance premium pricing, loss prediction and farmers' adjustment to climate challenges. AI analyzes extensive datasets on weather patterns, crop health, market trends for real-time policy customization, while blockchain eases automated claims processing through smart contracts, reducing costs and improving transparency.¹¹³ Companies such as Etherisc and Limonade have incorporated parametric insurance, offering automatic compensation calculated on predefined events rather than traditional damage assessments.

Furthermore, digital platforms and mobile technology have broadened access to agriculture insurance by facilitating claims filing process and policy management. Digital transformation improves customer experience and

¹¹² Miranda, M., & Vedenov, D. V. (2001). Innovations in agricultural and natural disaster insurance. *American Journal of Agricultural Economics*, 83(3), p. 653.

¹¹³ Venturini, R. E. (2025). Revolution in agricultural insurance: the integration of AI and blockchain for a more efficient and resilient sector. *Revista Sistemática*, 15(3), p. 192.

operational efficiency, while mobile apps enable farmers to purchase insurance, receive payouts, and report losses.¹¹⁴

Drone technology has significantly improved agricultural insurance assessments by improving accuracy, efficiency, and cost-effectiveness. Equipped with advanced sensors, drones capture high-resolution images that allow insurers to assess crop health, estimate yields, and evaluate damage with precision. Their ability to rapidly cover large farmland areas accelerates claims processing and reduces reliance on subjective manual inspections, which is especially crucial after natural disasters. Additionally, drones help mitigate fraud and improve risk management, leading to more accurate insurance policies tailored to farmers' needs. By fostering transparency and ensuring fair compensation, drone technology strengthens trust between farmers and insurers, ultimately benefiting the agricultural sector.¹¹⁵

Finally, innovations in agricultural insurance are progressively integrating conservation practices such as no-till and mini-till technologies to enhance risk mitigation and optimize claim management. A 2019 analysis of prevent-plant crop insurance claims across six Midwestern states showed that fields utilizing cover crops and no-till methods were 24% less likely to be classified as “prevent plant” and receive insurance payouts compared to conventionally managed fields. This finding underscores the potential of conservation agriculture to buffer against adverse weather conditions, thereby reducing both the incidence and magnitude of insurance claims.¹¹⁶

A Data-Driven Approach to Premium Calculation

The evolution of agricultural insurance has been profoundly influenced by advances in Big Data analytics, machine learning, and climate modelling. Recent literature highlights the increasing importance of data-driven risk assessment, particularly in the context of climate uncertainty and yield variability. Traditional methods of premium calculation often fail to capture the spatial and temporal

¹¹⁴ World Bank Group (2022). *Disruptive innovations boost uptake of agriculture insurance solutions in Kenya*. Retrieved March 19, 2025, from <https://www.worldbank.org/en/news/feature/2022/06/15/disruptive-innovations-boost-uptake-of-agriculture-insurance-solutions-in-kenya>

¹¹⁵ <https://husfarm.com/article/the-impact-of-drones-on-enhancing-agricultural-insurance-assessments>

¹¹⁶ Environmental Defence Fund (2023). *Cover crops reduce insurance claims and lower costs for taxpayers*. Retrieved March 19, 2025, from <https://business.edf.org/insights/cover-crop-insurance-claims>

complexities of climate risk, leading to inefficiencies in pricing and risk allocation. This study builds on recent advancements by proposing a precision-based insurance model tailored to the Serbian agricultural sector, focusing on wheat, corn, and soy cultivation.

By integrating machine learning, climate analytics, and actuarial modelling, this research offers an innovative framework for agricultural insurance, improving pricing accuracy and risk assessment. The proposed model serves as a data-driven decision support tool for insurers, facilitating more sustainable and resilient agricultural insurance policies in Serbia. Historical data from wide variety of climate, agriculture and market information serve as a fuel to novel approach of insurance companies' business model.

The proposed insurance premium calculation model is structured around the fundamental actuarial principle that premium is composed of expected loss and a risk adjustment factor multiplied with standard deviation of consecutive dry days. Formally, the premium is expressed as:

$$\text{Premium} = E(L) + \lambda * \sigma_{\text{CDD}}$$

Where $E(L)$ represents the expected loss, λ is the risk load factor, and σ_{CDD} denotes the standard deviation of consecutive dry days, serving as a measure of climate variability and systemic risk. This approach is consistent with the Sharpe ratio method, where the risk margin is proportional to the standard deviation of the insurer's cost.¹¹⁷

Expected loss is mathematically defined as:

$$E(L) = P(D) \times (Y_f - Y_o) \times P_f$$

Where $P(D)$ represents the probability of drought, Y_f is the expected yield, Y_o is the observed yield, and P_f is the market price of the respective crop.¹¹⁸

The primary objective of this research is to accurately estimate the expected loss by leveraging Big Data sources, including the Digital Atlas of Serbia and the Statistical Office of the Republic of Serbia.

¹¹⁷ Leblois, A., & Quirion, P. (2013). Agricultural insurances based on meteorological indices: realizations, methods and research challenges. *Meteorological Applications*, 20(1), pp. 1-9.

¹¹⁸ Kleshchenko, A. D., Lebedeva, V. M., Goncharova, T. A. et al. (2016). Estimation of drought-related yield loss using the dynamic statistical model of crop productivity forecasting. *Russian Meteorology and Hydrology*, 41, pp. 299-306.

At the core of this model is the integration of agricultural and climate Big Data to enhance the accuracy of premium calculations. The proposed methodology utilizes historical climate data from the Digital Atlas of Serbia, specifically focusing on wheat, corn, and soybean cultivation. The dataset encompasses two key climatic indicators—the aridity index and vegetation period—for the Čurug region, one of Serbia’s most fertile agricultural areas, covering the period from 1950 to 2020.

Aridity index (AI) has proved as critical indicator for assessing and predicting drought, for it distinguishes type of climate in respect of water availability. Furthermore, AI considers climatic data of precipitation (P), evapotranspiration (PET) and air temperature (T):¹¹⁹

$$AI = \left(\frac{P}{PET} \right)$$

where P is the monthly precipitation and PET is the monthly potential evapotranspiration. Typically, values below 0.5 indicate dry conditions.

According to the United Nations Environment Programme (UNEP)¹²⁰ classification criteria of climate risk, drought severity is classified into four categories: extreme, moderate, mild, and no drought, based on AI. Table 2 shows defined criteria.

Table 2. Drought Classification Criteria

Category	Aridity Index
Severe Drought	Less or equal than 0.2
Moderate Drought	Less or equal than 0.35
Mild Drought	Less or equal than 0.5
No Drought	else

Source: Budyko, M. I. (1958). *The Heat Balance of the Earth's Surface*. Soviet Geography, 2(4).

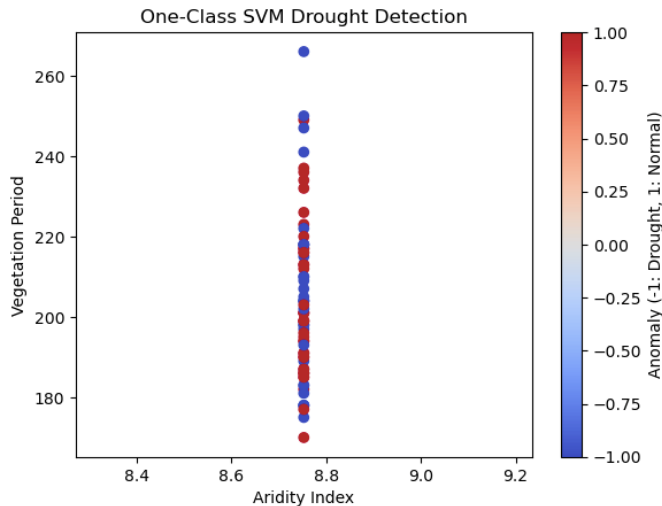
Upon analyzing the 70-year dataset of the most fertile agricultural region in Serbia, no recorded instances of drought were observed based on the United Nations Environment Programme (UNEP) classification. The Aridity Index (AI) values remained consistently above the threshold defining drought conditions, leading to a dataset where the column Drought contained only a single class: "No Drought." Given the absence of variation in drought classifications in Čurug

¹¹⁹ Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geographical Review*, 38(1), pp. 55-94.

¹²⁰ <https://www.unep.org>

region example, traditional supervised learning techniques, which rely on multiple class labels for training, were not applicable in the context.

Figure 5. One-Class SVM Drought Detection



Source: Author's calculations.

To address this challenge, an unsupervised anomaly detection approach was employed using the One-Class Support Vector Machine (One-Class SVM). One-Class SVM is a robust machine learning algorithm specifically designed for outlier detection in scenarios where only one class is well-represented in the data. It constructs a decision boundary around the majority class (in this case, normal conditions) and identifies deviations from this learned distribution as potential anomalies.¹²¹

The model was trained on two key climatic indicators: the Aridity Index and Vegetation Period, both of which play a crucial role in drought assessment. The trained One-Class SVM model assigned each data point to either the normal climatic condition class (1) or an anomalous (potential drought-like) class (-1). The resulting classification was visualized in Figure 5 (shown above), where the red-colored points represent data instances flagged as anomalies by the model. These instances, despite not meeting traditional drought classification criteria, highlight periods where climatic conditions exhibited slight deviations from the typical pattern observed over the seven-decade period.

¹²¹ Yin, S., Zhu, X., & Jing, C. (2014). Fault detection based on a robust one class support vector machine. *Neurocomputing*, 145, pp. 263-268.

Finally, the study integrates historical yield and price data of wheat, soybean, and corn with the Extreme Gradient Boosting (XGBoost) machine learning algorithm to enhance the accuracy of both yield and price forecasts, thereby improving the precision of agricultural insurance premium calculations. XGBoost constructs an ensemble of decision trees that iteratively correct prediction errors while incorporating regularization techniques to mitigate overfitting.¹²²

The dataset spans from 2005 to 2022, enabling the model to capture long-term yield variability and price-related influences. To account for temporal dependencies, lag features representing the previous year's yield values are introduced, allowing the model to learn patterns in yield fluctuations.

The dataset is standardized using StandardScaler to ensure numerical stability, while a train-test split method used data from 2005 to 2021 for model training and 2022 for validation. Separate XGBoost regression models are trained for each crop, utilizing a squared error loss function and hyperparameters optimized for predictive performance. Future yield and price predictions for the period 2024–2026 are generated iteratively, where the predicted values serve as inputs for subsequent years, enabling multi-year forecasting. Table 3 presents the predicted prices and yields for wheat, soybean, and corn.

Table 3. Predicted Prices and Yields for Wheat, Corn and Soy

Year	Wheat Yield	Wheat Price	Corn Yield	Corn Price	Soy Yield	Soy Price
2024	4.0998	17.5487	6.3984	16.0269	2.4001	43.6402
2025	3.4084	16.5514	6.2987	14.5077	2.1028	35.4479
2026	4.2973	17.8297	5.9001	14.3909	2.4001	34.7039

Source: Author's calculations

By integrating historical data with machine learning techniques, this approach enhances the accuracy of price, yield, and drought probability forecasts, leading to improved risk assessment in agricultural insurance. The incorporation of conservation practices, such as no-till and mini-till technologies, further strengthens risk mitigation by reducing insurance claims associated with adverse weather conditions. Additionally, emerging technologies like drones, IoT, and blockchain provide innovative solutions for real-time monitoring, data transparency, and automated insurance processing, and eventually trust between insurers and farmers. These advancements collectively optimize insurance

¹²² Chen, T., & Guestrin, C. (2016). XGBoost: A scalable tree boosting system. *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pp. 785-794.

pricing strategies, ensuring more precise policy design and fairer compensation mechanisms. Ultimately, the convergence of data-driven models and technological innovations transforms agricultural insurance into a more resilient and adaptive system.

The complete implementation of each machine learning model used in this study is available on GitHub at:

<https://github.com/bradickristina/agri-insurance.git>.

PART II

**ECONOMIC AND
INSTITUTIONAL ENVIRONMENT
FOR INSURANCE INNOVATION**

Chapter 6.

AN INNOVATIVE APPROACH TO MEASURING DEVELOPMENT ACHIEVEMENTS – SERBIA IN THE EUROPEAN CONTEXT

The world we live in is undergoing a profound social and planetary transformation, accompanied by growing uncertainty. The escalation of climate change risks as the greatest source of long-term concern¹²³, along with economic turbulence, stricter regulations, and technological accelerations, strongly influences movements in the insurance sector, which is itself changing and modernizing in line with the demands of the new era.

Key trends that will shape this sector include: the application of *predictive AI* technologies, which in the context of insurance can be used to assess risks, optimise policy prices, prevent fraud, and even personalise services for customers; *automation in the claims processing*, i.e., the use of technology, including artificial intelligence (AI) and robots, to automate various steps in the insurance claims process; the affirmation of *personalised insurance*, i.e., the creation of policies that are largely tailored to customers; the introduction of *IoT connected devices* to collect data that can help reduce risks, optimise premiums, or even speed up and make the claims process more efficient; the application of *telematics*, which combines telecommunications and computer science to collect, transmit, and analyse data (typically used in the automotive industry); the appearance of *emerging and unprecedented risks*, which are unpredictable and require new approaches in the insurance sphere.

Additionally, there is a very relevant trend of *integrating sustainability and Environmental, Social, and Governance - ESG criteria into the management of insurance companies*, which is seen as the only correct path.¹²⁴ This trend is closely linked to changes in the conceptualisation of development and the measurement of development achievements, which are the focus of this research.

¹²³ World Economic Forum (2025). *The Global Risk Report 2025*. Geneva: WEF, p. 4.

¹²⁴ See: <https://wint.ai>

1. HISTORICAL OVERVIEW OF MEASURING DEVELOPMENT ACHIEVEMENTS

During the post-war period, which spans more than seven decades, there has been a true evolution in the understanding of economic development, which was reflected in the way development achievements were measured, specifically in the evaluation of changes in human welfare. The traditional approach to national economic development, characteristic of the 1950s and 1960s, was marked by the dominance of economic growth, measured by the increase in GDP, either total or *per capita*. Although economic growth was highly valued by the creators of development policy, it was not considered the goal of economic development but rather the main indicator of development performance. Increasing the welfare of the population was the ultimate concern of development, but it was assumed that, in accordance with the 'trickle-down' theory¹²⁵, economic growth would automatically ensure the realisation of that goal, which is why it was placed at the center of attention.

By the end of the 1960s, the sense of satisfaction created by the post-war economic boom gradually gave way to disappointment caused by the social and ecological consequences of growth. This resulted in a sort of 'humanization' of the theory of economic growth and a shift in focus from increasing GDP to changes in welfare that arise from its growth.¹²⁶ Given the importance placed on improving welfare when measuring economic growth, two extreme viewpoints emerge. According to one, the primary task of statistics is to determine the contribution of economic activity to human welfare. According to the other, measuring economic growth should be separated from welfare and changes in it, and should be limited only to products and services that are part of market exchanges.¹²⁷ In most cases, these viewpoints do not confront each other in an extreme form. Insisting on measuring welfare in its strict sense would introduce so many subjective elements into the calculation that it would call into question the validity of the results obtained. On the other hand, loyalty to market transactions would be paid for by losing important items in the calculation of economic growth.

¹²⁵ Moore, H. L., & Saffron, W. (2022). Conceptualising and measuring prosperity. *GOLD VI Working Paper Series #11*, 3. Barcelona: United Cities and Local Governments.

¹²⁶ See: Jovanović Gavrilović, B. (1989). *Kvalitet privrednog rasta*. Belgrade: Savremena administracija, p. 4; and Jovanović Gavrilović, B., Gligorić Matić, M., & Jovanović Gavrilović, V. (2024). Quantity and Quality of Growth in the New Economic Reality. *Novi Ekonomist*, 18(35), p. 24.

¹²⁷ Mishan, E. J. (1967). *The Costs of Economic Growth*. London: Staples Press.

Thus, the problem essentially boiled down to finding the optimal degree of imputation into the existing system of measuring production and economic growth. There were proposals to adjust conventional indicators of economic growth to make them more sensitive to changes in income distribution and the position of the poor¹²⁸, or to take into account the damage done to the natural environment¹²⁹.

A number of authors, in an effort to overcome the shortcomings of GDP, reject the very idea of measuring welfare in monetary terms. Instead of making greater or lesser interventions in the existing system of calculating production and economic growth, they propose replacing aggregate value indicators with a set of social indicators. Pioneering research in this field was conducted under the auspices of the Institute for Social Development Research at the UN during the 1960s.¹³⁰

Efforts were also made to develop composite indicators of welfare that could replace or complement GDP. Among them, attention was drawn to the Physical Quality of Life Indicator (PQLI), based on three individual indicators: life expectancy at one year of age, infant mortality, and literacy.¹³¹ The PQLI, like the list of social indicators, was separate from GDP, and thus, there was a lack of synergy between the economic and social aspects of prosperity.

The mentioned shortcoming was addressed with the affirmation of the concept of human development and the introduction of the Human Development Index - HDI, probably the most well-known measure of development achievements, which combines economic and social indicators.¹³² The current definition of HDI lacks an ecological component, although there have been attempts to 'green' the index.¹³³ Indeed, the 2020 Human Development Report defined the Planetary Pressures-Adjusted HDI - PHDI, which takes into account planetary pressures,

¹²⁸ Chenery, H. B. et al. (1974). *Redistribution with Growth*. Oxford: Oxford University Press.

¹²⁹ Nordhaus, W., & Tobin, J. (1972). Is Growth Obsolete? *Economic Growth, Fiftieth Anniversary Colloquium*. New York: National Bureau of Economic Research.

¹³⁰ Hicks, N., & Streeten, P. (1979). Indicators of Development: The Search for a Basic Needs Yardstick. *World Development*, 7(6), p. 575.

¹³¹ Morris, M. D., & Liser, F. D. (1977). The PQLI: Measuring Progress in Meeting Human Needs. *Communique on Development Issue*, p. 32.

¹³² United Nations Development Program (1990). *Human Development Report*. New York: Oxford University Press.

¹³³ Atkinson, G. et al. (1997). *Measuring Sustainable Development: macroeconomics and the environment*. Cheltenham: Elgar, pp. 149-150.

i.e., the interaction between humans and the planet¹³⁴, but this index did not challenge the central position that the traditionally defined HDI holds in monitoring human development.

Alongside the idea of human development, the concept of sustainable development was also affirmed, which has become a universal development paradigm applicable to all countries of the world. It is a holistic approach to development that integrates economic, social, and ecological aspects, taking into account the interests of both present and future generations. Sustainable development has stimulated efforts to measure developmental achievements, which has resulted in numerous new indicators. A crucial role in this process has been played by various international initiatives, including the OECD World Forum on 'Statistics, Knowledge, and Policies', initiated in 2004¹³⁵, the organizing of the 'Beyond GDP' conference by the European Commission and its partners¹³⁶, as well as the publication of the influential Stiglitz-Sen-Fitoussi Commission report, which provided an important impulse for measuring economic performance and social progress.¹³⁷ A recent UN initiative should also be added to this, which opens the door for the introduction and institutionalization of a new global metric that goes 'beyond GDP,' focusing on the well-being of people and the planet, as well as sustainability.¹³⁸ The mentioned idea was incorporated into the 'Pact for the Future', adopted at the UN's 'Summit of the Future' in 2024, with the aim of identifying a limited number of 10-20 universally applicable headline indicators of progress in sustainable development that complement and surpass GDP.¹³⁹ Given the key role of the UN in the standardization and institutionalization of GDP, this initiative could facilitate a global shift toward measuring development achievements beyond GDP. Work is also underway on the construction of the 2025 SNA, which represents an

¹³⁴ United Nations Development Program (2020). *Human Development Report 2020: The Next frontier - Human development and the Anthropocene*. New York: UNDP, pp. 233-244.

¹³⁵ OECD (2004). *OECD World Forum on Key Indicators*. Palermo: OECD.

¹³⁶ European Commission & European Parliament (2009). *Beyond GDP – Measuring progress, true wealth, and the well-being of nations*. Luxembourg: Publications Office of the European Union.

¹³⁷ Stiglitz, J., Sen, A., & Fitoussi, J-P. (2009). *The Measurement of Economic Performance and Social Progress Revisited*. OFCE.

¹³⁸ United Nations System Chief Executives Board for Coordination (2022). *Valuing what counts - United Nations system-wide contribution on progress beyond gross domestic product (GDP)*. New York: CEB.

¹³⁹ United Nations (2024). *Summit of the Future Outcome Documents*. New York: UN, p. 34.

important step toward a more comprehensive measurement system that includes a chapter on well-being and sustainability.¹⁴⁰ To achieve a truly integrated and multidimensional accounting system, further adjustments are needed, but it is essential to recognize the importance of creating such a system.

Some of the existing indicators, compatible with the idea of sustainable development, 'adjust' GDP, such as the Index of Sustainable Economic Welfare¹⁴¹, which was later revised and renamed the Genuine Progress Indicator¹⁴², Green GDPs calculated using different methodological approaches¹⁴³, Adjusted Net Savings, also known as Genuine Savings¹⁴⁴, and health-adjusted GDP *per capita*¹⁴⁵. Others are linked together to form a set of sustainable development indicators (economic, social, ecological), with their final aggregation missing. As an example, we can mention the comprehensive list of indicators through which the achievement of the UN Sustainable Development Goals by 2030 is monitored. A special group consists of composite indices of development achievements that combine several different measures (where GDP may or may not be included) into a single number.

Thanks to the abundance of quantitative and qualitative information available today, it is possible to track progress in economic, social, and ecological terms through multidimensional, complex indicators. Only aggregate indices, which cover various aspects of sustainable development and well-being, can compete with GDP as an undeniably important but insufficient indicator for measuring development achievements. Within the 'beyond GDP' development discourse, an alternative metric of well-being, happiness, and social progress has been built, based on economics as a scientific discipline, but also psychology. The most well-known composite indices of development achievements related to the

¹⁴⁰ <https://unstats>

¹⁴¹ Daly, H. E., & Cobb, J. B. (1989). *For the common good: redirecting the economy towards community, the environment, and a sustainable future*. Boston: Beacon Press.

¹⁴² Cobb, C., Halstead, T., & Rowe, J. (1995). *The Genuine Progress Indicator: Summary of Data and Methodology*. San Francisco.

¹⁴³ United Nations (2003). Handbook of National Accounting: Integrated Environmental and Economic Accounting. *Studies in Methods*, 61(1).

¹⁴⁴ Pearce, D., & Atkinson, G. (1993). Capital Theory and the Measurement of Sustainable Development: An Indicator of Weak Sustainability. *Ecological Economics*, 8.

¹⁴⁵ European Commission (2023). *Strategic Foresight Report 2023*. Luxembourg: Publications Office of the European Union.

concept of sustainability are: Ecological Footprint¹⁴⁶, Living Planet Index¹⁴⁷, Happy Planet Index¹⁴⁸, Social Progress Index¹⁴⁹, and OECD's Better Life Initiative¹⁵⁰. This group also includes the Legatum Prosperity Index (LPI), which is the subject of special attention in this chapter.

2. PROSPERITY INDEX AS A COMPREHENSIVE MEASURE OF DEVELOPMENT ACHIEVEMENTS

Conceptual Framework

The Prosperity Index of the Legatum Institute (now the Prosperity Institute) - LPI is a comprehensive indicator of economic progress and quality of life, encompassing both material and non-material well-being. As such, it far exceeds traditional macroeconomic measures of national prosperity that rely solely on indicators of material wealth, such as GDP *per capita*. This index is also unique in that, in addition to objective variables, it includes subjective variables that provide insight into people's perception of their standard of living and well-being. This aligns with the growing interest in research on 'subjective well-being' (commonly known as 'the science of happiness'), which is important for a holistic assessment of prosperity. Furthermore, the LPI is one of the few indices that includes an ecological component, which, together with the economic and social dimensions, represents the main pillars of sustainable development.

The Prosperity Index stems from the very definition of the concept. True prosperity, according to the Prosperity Institute, assumes that people have the opportunity to progress and realise their potential while simultaneously contributing to the progress of the country. This implies an *inclusive society* in which the fundamental freedoms and security of each individual are protected. In a prosperous society: people live in peace, free from oppression, crime, and the threat of violence; the dignity of every individual is respected, and freedom of speech, religion, and assembly are protected; governing institutions operate

¹⁴⁶ Wackernagel, M., & Rees, W. E. (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, BC: New Society Publishers.

¹⁴⁷ Loh, J. J. et al. (1998). *Living Planet Report 1998: Overconsumption is driving the rapid decline of the world's natural environments*. Gland: World Wildlife Fund for Nature.

¹⁴⁸ Marks, N. et al. (2006). *The Happy Planet Index*. London: New Economics Foundation.

¹⁴⁹ Porter, M. E., Stern, S., & Loría, R. A. (2013). *Social progress index 2013*. Washington, DC: Social Progress Imperative.

¹⁵⁰ OECD (2020). *How's Life? 2020: Measuring Well-Being*. Paris: OECD Publishing.

professionally, are accountable to citizens, and subject to the rule of law; stable families and broader communities instill values that shape culture and build trust needed for social progress. The driving force of prosperity is an *open economy* that relies on the ideas and talents of people to create a sustainable path out of poverty. In such circumstances: property rights are protected, allowing the flow of investments; business regulations enable entrepreneurship, competition, and innovation; open markets and high-quality infrastructure facilitate trade and business; fiscal and monetary policies are responsibly used to stimulate employment, productivity, and sustainable economic growth. Prosperity is built by *empowered people* who create a society focused on promoting well-being. This means the following: everyone is able to build a life free from poverty; people care for their physical and mental health and have access to effective healthcare; education is valued, and everyone has access to high-quality education to realize their potential; the natural environment is carefully respected, taking into account the interests of both present and future generations. Finally, it is worth noting that from the perspective of prosperity, it is not only important what we receive, but also who we become.¹⁵¹

Measuring national prosperity is an important task for every country. A well-constructed prosperity index can help policymakers assess the achieved results, identify key trends over time, pinpoint limiting factors on the path to prosperity, and define agendas for further growth and development. The trajectory from poverty to prosperity differs from country to country. The specific circumstances that characterize each country are crucial in determining priorities. Diagnosing limiting factors for development that takes into account the specific circumstances of each country is a prerequisite for creating relevant development strategies.

Methodology

The conceptual framework of the Legatum Institute for measuring prosperity, which serves as the basis for our research, covers 3 domains as the foundations of prosperity, divided into 12 pillars that address fundamental aspects of prosperity. (See Table 1) The pillars are further decomposed into a total of 67 elements, which represent key policy areas such as investor protection, basic education, rule of law, macroeconomic stability, and air pollution. In calculating the LPI, 300 indicators were used, with each element having between one and eight indicators, and each pillar having between five and eight elements.¹⁵²

¹⁵¹ See: Legatum Institute (2023). *The 2023 Legatum Prosperity Index*. London: Legatum Institute, p. 7.

¹⁵² Ibid, pp. 92-93.

Since the indicators are expressed in different units, their normalization has been carried out to make the comparison between the indicators and countries meaningful. For this purpose, the distance-to-frontier (DTF) approach was used, which compares the performance of a given country in terms of a particular indicator with the values of the assumed best and worst-case scenarios for that indicator. Accordingly, the distance-to-frontier score reflects the relative position of the country. This approach also allows for the comparison of scores over time.

Table 1. The building blocks of prosperity: domains and pillars of prosperity

Domains		
Inclusive Societies	Open Economies	Empowered People
Pillars		
Safety and Security	Investment Environment	Living Conditions
Personal Freedom	Enterprise Conditions	Health
Governance	Infrastructure and Market Access	Education
Social Capital	Economic Quality	Natural Environment

Source: Authors' own representation

Each indicator is assigned a weight that reflects its level of importance within a given element in influencing prosperity. Typically, four weights are used: 0.5, 1, 1.5, or 2. The distance-to-frontier scores for each indicator are multiplied by the corresponding weight, and then summed to obtain the score for each element. The same procedure is repeated to determine the scores for the pillars with the elements within them. Domain scores are obtained by assigning equal weights to each pillar. The LPI is then calculated as the average of the scores of the three domains, with each domain receiving the same weight.

Since the chosen weighting method is only one of the possible approaches, the sensitivity of the LPI to changes in the selection of weights has been tested. The actual weighting approach is compared with (a) equally weighted indicators and elements, and (b) a randomized weighting approach derived using Monte Carlo randomization simulations. It was shown that the scores and rankings of countries are more influenced by variations in the values of the indicators themselves than by the applied weights, which indicates the robustness of the empirical results obtained through the application of the LPI.¹⁵³

¹⁵³ More detailed methodological explanations can be found in: Legatum Institute (2019). *The Legatum Prosperity Index 2019 - Methodology Report*. London: Legatum Institute.

While the LPI score provides an overall assessment of a country's prosperity, the scores for each domain/pillar/element reveal the results achieved in a specific aspect of prosperity. The main domains within the LPI reflect the institutional, economic, and social dimensions of prosperity. However, it would be analytically desirable and justifiable to exclude the element Natural Environment from the third domain, thus obtaining an ecological dimension, which, along with the economic and social dimensions, constitutes an important determinant of sustainable development as a generator of prosperity.

Table 2. Twelve pillars of LPI classified into four dimensions

Dimensions			
Institutional	Economic	Social	Environmental
Pillars			
Safety and Security	Investment Environment	Living Conditions	Natural Environment
Personal Freedom	Enterprise Conditions	Health	
Governance	Infrastructure and Market Access	Education	
Social Capital	Economic Quality		

Source: Authors' own representation

3. ANALYSIS OF DEVELOPMENT ACHIEVEMENTS IN SERBIA AND OTHER EUROPEAN COUNTRIES

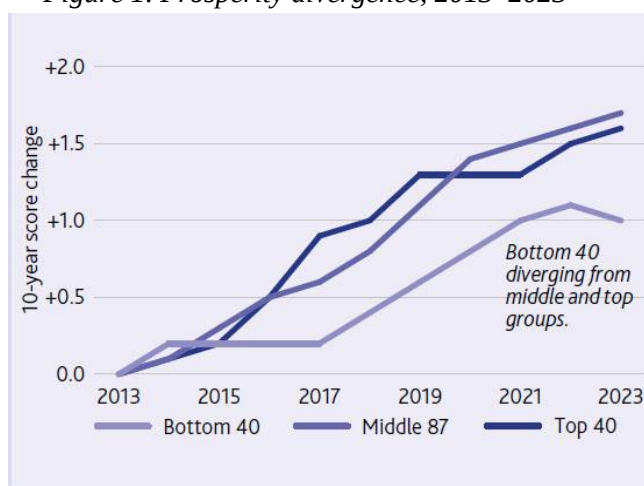
The Prosperity Index, as a holistic measure of human progress, offers a unique insight into how prosperity is shaped and changing in nearly all countries around the world. The LPI analysis covers 167 countries, categorized into eight regions, representing 99.4% of the global population. Europe is divided into Western and Eastern Europe, with Serbia belonging to the Eastern European group of countries.

Data for 2023 shows a concerning global trend – for the third consecutive year, prosperity has stagnated due to the weakening of institutions and democratic processes. The fact that institutions are deteriorating represents a ‘red flag’ signallingg potential problems in countries around the world with political instability, corruption, or other systemic issues that make it difficult for them to fully realise their potential. Recent economic shocks that have rocked the world have most severely affected the least prosperous countries, which also have the lowest capacity to cope with them. However, even these countries have made

progress in the last decade in terms of basic living conditions, narrowing the gap that separates them from the rest of the world.¹⁵⁴

When considering all dimensions of prosperity, a clear divergence is evident in the results achieved globally during the observed period (2013 - 2023) between the 40 countries ranked the lowest in 2013 and the remaining 87 plus 40 countries that were positioned in the middle or at the top of the list in the same year (see Figure 1). This actually means that the gap between the average score of the bottom 40 and the middle and top 87 plus 49 countries is larger in 2023 than in 2013. Although prosperity scores have increased in the lowest-ranked countries, the rate of growth has been slower compared to the rest of the world.

Figure 1. Prosperity divergence, 2013–2023



Source: Legatum Institute (2023), *op. cit.*, p. 26.

The reason for this divergence lies in structural factors within the institutional and economic dimensions of prosperity. In the institutional domain, the lag behind more prosperous countries is particularly evident in the pillars of Safety & Security and Personal Freedom, while in the economic sphere, it is noticeable in Enterprise Conditions and Economic Quality.¹⁵⁵ In situations where the focus is placed on poverty reduction rather than on building prosperity, improvements in basic living conditions, i.e., in the social dimension, in the 40 countries with the lowest levels of prosperity, have not been accompanied by corresponding progress in the institutional and economic spheres. As a result, these improvements are unsustainable.

¹⁵⁴ Legatum Institute (2023), *op. cit.*, p. 10.

¹⁵⁵ *Ibid*, pp. 27-28.

Among the eight regions of the world, in terms of overall prosperity ranking, Western Europe occupies the first position, while Eastern Europe ranks fourth.

Table 3. Ranking of European Regions According to LPI and Prosperity Pillars

	Overall Prosperity Rating	Safety and Security	Personal Freedom	Governance	Social Capital	Investment Environment	Enterprise Conditions	Infrastructure and Market Access	Economic Quality	Living Conditions	Health	Education	Natural Environment
Western Europe	1	1	1	1	2	2	2	2	2	1	1	2	1
Eastern Europe	4	4	4	5	5	4	5	4	4	3	5	3	4

Source: Legatum Institute (2023), *op. cit.*, p. 32.

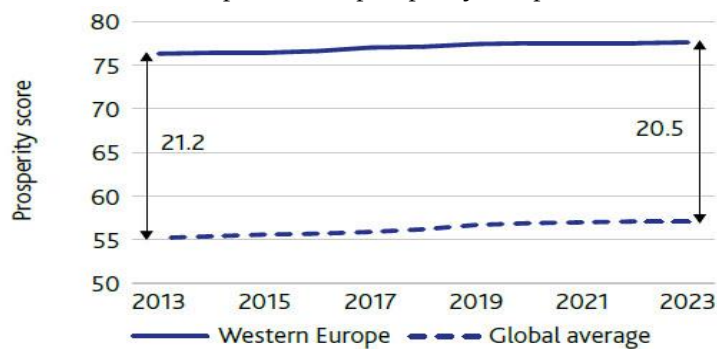
When looking at the dimensions of prosperity, Western Europe is particularly superior in the Environmental and Institutional dimensions, while Eastern Europe records relatively better performance in the Social dimension.

In terms of the prosperity pillars, in all cases where Western Europe ranks second, North America holds the primacy. Eastern Europe lags behind Western Europe and North America in every pillar, and in most pillars it also falls behind East Asia and the Pacific. In some pillars, Eastern Europe even trails behind Latin America and the Caribbean, as well as Central and South Asia.

Over the past decade, the LPI score for Western Europe has increased, but at a slightly slower pace than the global average, resulting in a narrowing of the distance between the two (see Figure 2). During this period, the region has experienced improvements across all prosperity pillars, except for Safety & Security and Personal Freedom, where some deterioration was observed, as well as Social Capital, which has seen stagnation. The most significant improvements were observed in the Infrastructure & Market Access pillar, as well as in Education (the latter primarily due to an increase in tertiary education participation).¹⁵⁶

¹⁵⁶ Ibid, p. 34.

Figure 2. Western Europe: Global prosperity comparison, 2013–2023



Source: Legatum Institute (2023), *op. cit.*, p. 34.

Western Europe, as the most prosperous region in the world, includes the top nine highest-ranked countries globally, including Denmark, which holds the leading position in the LPI in 2023 (See Table 4) Compared to 2013, Denmark has improved its position, rising from fourth place to first, surpassing Sweden, Norway, and Switzerland.

Table 4. Ranking of Western European Countries According to LPI, 2013 and 2023

Country	Global rank		Country	Global rank	
	2013	2023		2013	2023
Denmark	4	1	United Kingdom	10	12
Sweden	1	2	Austria	11	14
Norway	2	3	Belgium	20	18
Finland	5	4	France	21	23
Switzerland	3	5	Spain	24	24
Netherlands	6	6	Portugal	29	26
Luxembourg	8	7	Malta	27	28
Iceland	14	8	Italy	30	30
Germany	9	9	Cyprus	31	34
Ireland	15	11	Greece	42	40

Source: Authors' own representation of data taken from Legatum Institute (2023), *op. cit.*, p. 22.

Austria is the only country in Western Europe whose prosperity level, measured by LPI, has not increased in the last decade, largely due to weak performance in the area of Economic Quality. In contrast, Greece has made the most progress in

the region during the observed period, which was marked by relative political stability and austerity policies, yet it remains the least prosperous.¹⁵⁷

The prosperity index in the Eastern European region grew faster than the global average during the 2013–2023 period, resulting in an increased gap between the two (see Figure 3). Improvements are visible across all pillars of prosperity, except for Personal Freedom, where a noticeable decline has occurred, and Safety & Security, which saw a slight deterioration. Governance, on the other hand, is characterised by stagnation. Unlike these cases, the Social Capital pillar, which also belongs to the Institutional dimension, saw a very pronounced improvement in prosperity over the observed decade. Significant progress, much more pronounced than in Western Europe, was also recorded in the Infrastructure & Market Access pillar within the Economic dimension of prosperity.

Figure 3. Eastern Europe: Global prosperity comparison, 2013–2023



Source: Legatum Institute (2023), *op. cit.*, p. 40.

The rank of Eastern European countries ranges from 21st place, held by Estonia, to 92nd place, which corresponds to Azerbaijan. (See Table 5) Estonia was already among the leading Eastern European countries in 2013, and since then, it has improved its global position in the LPI by two places. In the Economic Quality pillar, Estonia is ranked 14th in the world, which is an improvement of 9 places compared to the starting position in 2013.¹⁵⁸

Hungary progressed the slowest in the region, having recorded a decline in the score in the Institutional dimension, specifically in the pillars of Personal Freedom and Governance. Lithuania, which ranks among the five most prosperous countries in Eastern Europe, achieved the greatest progress over the observed decade. This is particularly noticeable in the Social Capital pillar, where there is a positive shift of as much as 30 places, albeit from a very low starting

¹⁵⁷ Ibid, p. 35.

¹⁵⁸ Ibid, p. 41.

position. Azerbaijan remains the least prosperous country in Eastern Europe, despite ranking second in the region in terms of progress dynamics during the observed decade.¹⁵⁹

Table 5. Ranking of Eastern European Countries by LPI, 2013 and 2023

Country	Global rank		Country	Global rank	
	2013	2023		2013	2023
Estonia	23	21	Serbia	66	52
Czechia	28	24	Georgia	64	53
Slovenia	25	27	North Macedonia	57	55
Latvia	36	31	Armenia	76	61
Lithuania	38	32	Albania	65	65
Slovakia	35	35	Moldova	86	70
Poland	34	37	Bosnia and Herzegovina	77	72
Croatia	44	41	Ukraine	94	74
Hungary	40	42	Russia	87	77
Romania	50	45	Belarus	83	78
Bulgaria	49	48	Azerbaijan	104	92
Montenegro	52	49			

Source: Authors' own representation of data taken from: Legatum Institute (2023), op. cit., p. 22.

According to the data in Table 5, Serbia ranks 52nd in the world by LPI in 2023. It is positioned lower than all Western European countries, as well as Eastern European EU member states. Among the candidates for EU membership, only Montenegro ranks ahead of Serbia. Compared to 2013, our country has advanced by as much as 14 places on the global prosperity scale, with its prosperity score increasing from 57.9 to 62.8.¹⁶⁰ Throughout the observed period, Serbia's LPI has exceeded the global average, and after 2017, it has also been higher than the average for Eastern European countries (see Figure 4).

Over the observed decade, our country has made progress in all dimensions of prosperity, measured by the value of the corresponding index, as well as its relative position in the world. This progress was particularly evident in the Economic dimension, where Serbia recorded a positive shift of 17 places on the global prosperity ranking, along with an improvement of 35 places in the Economic Quality pillar, which placed us among the top 10 countries with the greatest progress in this pillar.¹⁶¹ Serbia also performs well in the Social Capital pillar, where it recorded a significant jump of 93 places, the largest after China.

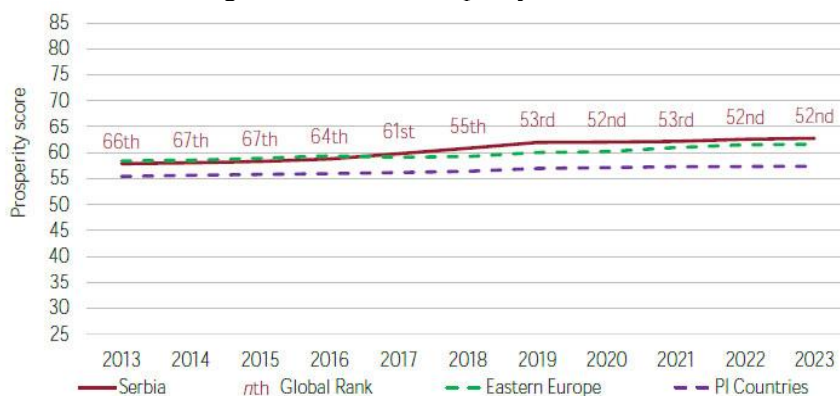
¹⁵⁹ Ibid.

¹⁶⁰ Country Profiles: Legatum Prosperity Index 2023, <http://www.prosperity.com>

¹⁶¹ Ibid.

On the other hand, the prosperity score in Serbia decreased in two pillars – Personal Freedom and Governance, which led to a drop in the country’s global ranking by ten and twenty places, respectively.

Figure 4. Serbia: Prosperity over time



Source: <https://www.prosperity.com>

In 2023, Serbia holds the highest rank among the observed countries in the Social Capital pillar (38th place), and the lowest rank in the Natural Environment pillar (131st place) (see Table 6).

Table 6. Serbia: Prosperity scores and ranks by pillars in the world, 2013-2023

Pillars	Prosperity score		Rank - Global	10-year rank change
	2013	2023	2023	
Safety and Security	71.7	79.8	44	+17
Personal Freedom	65.6	60.5	75	-10
Governance	48.6	44.8	96	-20
Social Capital	43.1	61.3	38	+93
Investment Environment	48.0	54.5	78	+10
Enterprise Conditions	49.0	54.0	82	+23
Infrastructure & Market Access	50.4	60.5	66	+2
Economic Quality	47.3	55.4	61	+35
Living Conditions	81.9	87.7	41	+7
Health	71.3	71.9	80	+2
Education	70.0	73.0	45	+5
Natural Environment	47.4	49.6	131	+21

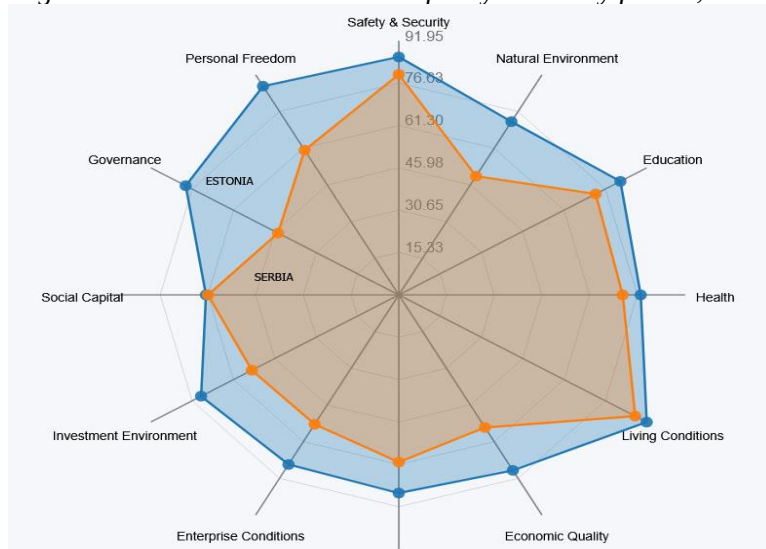
Source: Authors' own representation of data taken from <http://www.prosperity.com>

In Figure 5, the prosperity scores by pillars for Serbia in 2023 are visually represented. The country records the best result in the Living Conditions pillar (this was also the case in 2013), while the worst result is in the Governance pillar (in 2013, the lowest score was in the Social Capital pillar).

In comparison to Estonia, which is represented on the same graph as the most prosperous country in Eastern Europe, Serbia fares worse in all pillars, although the difference in Social Capital is negligible (61.9 for Estonia compared to 61.3 for Serbia). The lag is particularly pronounced in the Governance pillar. A similar situation existed in 2013, although in the meantime, Serbia made significant progress in the Social Capital pillar, while the gap in Governance has widened to Serbia's disadvantage.

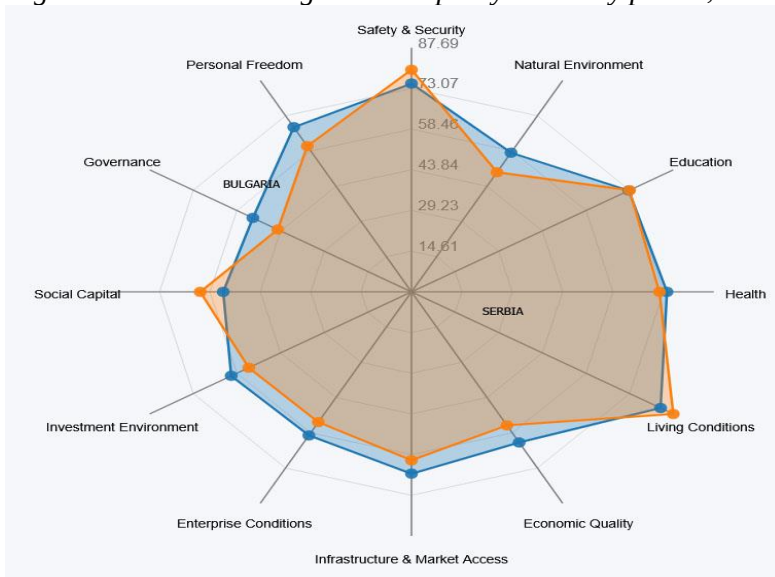
Compared to Bulgaria, the least prosperous country in the European Union from Eastern Europe, Serbia is superior in three pillars – Safety & Security, Social Capital, and Living Conditions, as shown in Figure 6 (in 2013, Bulgaria recorded a better score in the first two of these three pillars). The biggest difference in score to the detriment of Serbia is noticeable in Governance, which, as an important pillar within the Institutional dimension of prosperity, remains Serbia's weakest point.

Figure 5. Serbia and Estonia: Prosperity scores by pillars, 2023



Source: Authors' own representation based on the data from <http://www.prosperity.com>

Figure 6. Serbia and Bulgaria: Prosperity scores by pillars, 2023



Source: Authors' own representation based on the data from <http://www.prosperity.com>

The relative position of the Western Balkan countries (which includes Serbia) within the Eastern European region is presented in Table 7. In 2023, Montenegro recorded the highest prosperity score, while Bosnia and Herzegovina had the lowest. All countries increased their LPI and improved their rankings within Eastern Europe during the observed period, excluding Albania, which remained in the same position after ten years. The ranking of the Western Balkan countries has somewhat changed during this period, as Serbia surpassed North Macedonia and took second place in this regional group.

Table 7. Ranking of Western Balkan Countries by LPI, 2013 - 2023

Country	Prosperity score		Rank – Eastern Europe	10-year rank change
	2013	2023		
Albania	58.0	60.7	17	0
Bosnia and Herzegovina	56.6	59.1	19	+5
North Macedonia	59.6	62.0	15	+2
Montenegro	61.9	65.0	12	+3
Serbia	57.9	62.8	13	+14

Source: Authors' own representation based on the data from <http://www.prosperity.com>

Regarding the pillars of prosperity (see Table 8), Serbia's position is relatively poor in most of those belonging to the Institutional dimension (in terms of Personal Freedom, our country is even last in the observed group). An exception

is Social Capital, where in 2023, Serbia recorded better results than all other Western Balkan countries. Our country is also worse positioned in the pillars categorized under the Economic dimension, except for the Economic Quality pillar, where it ranks first in the Western Balkans. In terms of Macroeconomic Stability, as an element of prosperity within the mentioned pillar, Serbia ranked 8th in the world in 2023, having improved its position by as much as 38 places over the past ten years.

Good performance is also noticeable in the GDP *per capita* growth element, where Serbia ranks 13th globally, with an improvement of 52 places in its relative position.¹⁶² Significant progress on the prosperity scale is also visible in all other elements of Economic Quality. Serbia's advantages are evident in the Social dimension, especially in the pillars of Living Conditions and Education, where we are undeniably first. When it comes to the Environmental dimension, our country has below-average results and lags not only behind Montenegro but also Albania and North Macedonia.

Table 8. Western Balkan Countries: Prosperity scores by pillars, 2023

Pillars	Prosperity scores				Serbia
	Albania	Bosnia and Herzegovina	Macedonia	Montenegro	
Safety and Security	74.9	78.7	75.8	80.9	79.8
Personal Freedom	61.6	62.7	64.7	68.6	60.5
Governance	41.4	38.7	48.5	55.9	44.8
Social Capital	47.5	54.9	55.7	59.3	61.3
Investment Environment	55.2	51.4	60.9	56.4	54.5
Enterprise Conditions	54.9	47.6	55.1	64.1	54.0
Infrastructure and Market Access	61.6	57.6	58.4	63.2	60.5
Economic Quality	45.4	52.4	52.7	54.0	55.4
Living Conditions	76.2	84.4	83.4	83.7	87.7
Health	73.9	70.5	72.6	68.4	71.9
Education	70.1	61.9	61.0	71.7	73.0
Natural Environment	58.6	48.6	54.6	53.7	49.6

Source: Authors' own representation based on the data from <http://www.prosperity.com>

¹⁶² For a more detailed insight into the recent macroeconomic results of Serbia's economy, see: Jovanović Gavrilović, B., Gligorić Matić, M. & Jovanović Gavrilović, V. (2024). Macroeconomic Conditions: What We Can Expect? In: *Transformation of the Insurance Market – Responses to New Challenges*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 23-46.

The results Serbia has achieved in terms of prosperity during the 2013-2023 period are clearly diverse. The scores attained across dimensions, pillars, and elements serve as a strong guideline for policymakers on the direction they should take in order to improve the country's performance in various areas in the coming years. The gap in the results recorded over the observed decade across the four key dimensions of prosperity should certainly be reduced, as these dimensions are interconnected. Only synchronized progress in various aspects of prosperity, which mutually support each other, ensures its sustainability.

Quantifying prosperity as a multidimensional concept is a complex and delicate task. The LPI index, which we used in our research, is not an ideal measure of achieved development outcomes, but it is certainly a step in the right direction. This composite indicator allows for a critical reassessment and reshaping of existing development models and policies to achieve the desired goals. However, there is still considerable room for improving this index (which includes simplifying its structure, potentially separating the environmental dimension), in order to make it more suitable for understanding and analysis, something that is actively being worked on within the Prosperity Institute.

ECONOMIC UNCERTAINTY IN SERBIA: SOME ECONOMETRIC EVIDENCE

Over the past two decades, several major events, including the global financial crisis, Brexit, the US-China trade war, the COVID-19 pandemic and the Russian invasion of Ukraine, have significantly increased global uncertainty and impacted economies around the world. Increased uncertainty can strongly influence the decisions and behaviour of market participants and policy makers. High levels of uncertainty about future economic conditions may cause companies to postpone investment and hiring, while consumers concerned about their future income and job security may respond by saving more and spending less. As uncertainty increases, investors expect higher returns for greater risk, which ultimately drives up financing costs.¹⁶³ In addition, some studies suggest that as uncertainty increases, economic agents tend to react less quickly to business changes, reducing the effectiveness of monetary and fiscal policy.¹⁶⁴

Since uncertainty influences economic development, every economy has an interest in developing an indicator that monitors changes in uncertainty. A central question in empirical research is how to measure uncertainty, and in recent years, this topic has been widely studied by researchers. Various approaches to measuring uncertainty have been developed. The result is indicators that capture uncertainty in economic factors such as macroeconomic uncertainty, monetary policy uncertainty, inflation uncertainty, economic policy uncertainty and more.

One approach is based on the use of directly observable proxies for uncertainty. A commonly used indicator is the Chicago Board Options Exchange Volatility Index (VIX), which measures the implied volatility of the S&P 500 Index.¹⁶⁵ The second approach is based on observing the frequency of keywords related to

¹⁶³ Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives*, 28, pp. 153-176.

¹⁶⁴ Aastveit, K. A., Natvik, G. J., & Sola, S. (2017). Economic uncertainty and the influence of monetary policy. *Journal of International Money and Finance*, 76, pp. 50-67; Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., & Terry, S. J. (2018). Really uncertain business cycles. *Econometrica*, 86, pp. 1031-1065.

¹⁶⁵ Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica*, 77, pp. 623-685; Basu, S., & Bundick, B. (2017). Uncertainty shocks in a model of effective demand. *Econometrica*, 85, pp. 937-958.

uncertainty in newspaper articles.¹⁶⁶ These uncertainty indicators are based on the idea that when important events, such as political or economic shocks, occur, the number of articles covering these topics increases. The third approach uses surveys of companies, households and other market participants to create uncertainty indicators. The survey-based measures of uncertainty depend on the type of survey. Some indicators are based on the dispersion of professional forecasters' subjective forecasts¹⁶⁷, while others reflect firms' and households' views on uncertainty regarding various economic aspects such as production, purchases, prices, unemployment, etc.¹⁶⁸ The fourth approach uses an econometric framework to construct an uncertainty indicator. The prominent measure in this approach is the macroeconomic uncertainty indicator.¹⁶⁹ This indicator is created by aggregating the uncertainty of individual macroeconomic variables, defined as the volatility of the forecast error of the series.

In this chapter, we consider the index of economic uncertainty in Serbia based on the data defined by Thomson Reuters MarketPsych Indices in order to econometrically analyse its main dynamic properties.¹⁷⁰ We are primarily interested in identifying the extreme observations that indicate the increase in economic uncertainty. The modelling of extremes is a topic of extreme value theory, which provides a mathematical framework for considering the tails of the probability distribution of random variables.¹⁷¹ However, our intention is to extract extreme observations by looking at the entire data set and treating them

¹⁶⁶ Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, 131, pp. 1593-1636; Husted, L., Rogers, J. H., & Sun, B. (2020). Monetary policy uncertainty. *Journal of Monetary Economics*, 115, pp. 20-36.

¹⁶⁷ Ozturk, E. O., & Sheng, X. S. (2018). Measuring global and country-specific uncertainty. *Journal of International Money and Finance*, 88, pp. 276-295. Grishchenko, O., Mouabbi, S., & Renne, J. P. (2019). Measuring inflation anchoring and uncertainty: A US and euro area comparison. *Journal of Money, Credit and Banking*, 51, pp. 1053-1096.

¹⁶⁸ Bachmann, R., Elstner, S., & Sims, E. R. (2013). Uncertainty and economic activity: Evidence from business survey data. *American Economic Journal: Macroeconomics*, 5, pp. 217-249; Leduc, S., & Liu, Z. (2016). Uncertainty shocks are aggregate demand shocks. *Journal of Monetary Economics*, 82, pp. 20-35.

¹⁶⁹ Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring uncertainty. *American Economic Review*, 105, pp. 1177-1216.

¹⁷⁰ <https://www.lseg.com/data-analytics>

¹⁷¹ Embrechts, P., Kluppelberg, C., & Mikosch, T. (2008). *Modelling Extremal Events*. Berlin: Springer; Mladenović, P. (2024). *Extreme Values In Random Sequences*. Cham: Springer.

as additive outliers.¹⁷² Several techniques are used, originating from different statistical approaches. Applying different statistical methods can improve the robustness of the results.

The appropriate consideration of additive outliers is relevant from an econometric and economic point of view. If these outliers are neglected, standard econometric tools can lead to incorrect specifications of univariate and multivariate time series models, which in turn can lead to poor performance in the forecasting.¹⁷³ Furthermore, misleading economic conclusions can be drawn. Therefore, the presence of outliers must be treated with caution.

The above is also important for technical, i.e. mathematical statistical organization of insurance that represents the key specificity of insurance. Insurance has a large number of functions: the function of protection, i.e. asset protection, social function, financial accumulator function, promotes exchange and trade, contributes to more efficient allocation of capital, etc. The basic function of insurance is to provide economic protection to insurance users against the risks they are exposed to. In order to fulfill the aforementioned function, insurance companies carry out the timely transformation of smaller amounts of accumulated insurance premiums into larger amounts of assets (reserves). The aforementioned funds can be invested in the financial market until the maturity of contractually defined obligations towards insurance beneficiaries. Non-life insurance contracts are usually concluded for a period of one year, and life insurance contracts are concluded for several years (10, 20, 30, etc.). Depending on the type of insurance, it is necessary to harmonize the maturity of obligations and sources of funds. The goal of investing is to obtain an adequate return and capital gain with as little risk as possible.

Optimizing the portfolio of insurance companies is highly dependent on the relationship between economic uncertainty and financial markets. The situation is similar with voluntary pension funds, since the amounts of pension compensation depend to a large degree on the return on invested contribution funds in the financial markets. Depending on the relationship between economic uncertainty and financial markets, voluntary pension funds will opt for an active or passive portfolio management strategy. An active portfolio management strategy implies more frequent portfolio changes with the aim of adapting to new situations. A passive strategy involves buying and holding a security for a long time with minor and infrequent changes. Both insurance companies and pension

¹⁷² Wei, W. W. S. (2006). *Time Series Analysis: Univariate and Multivariate Methods*, 2nd ed., Boston: Pearson-Addison Wesley.

¹⁷³ Castle, J. L., Clements, M. P., & Hendry, D. F. (2016). An overview of forecasting facing breaks. *Journal of Business Cycle Research*, 12, pp. 3-23.

funds are cautious investors where the key investment principles are liquidity and safety, and only then profitability.

In addition, the pattern of time-varying conditional variability of the data is analyzed in the context of GARCH (generalized autoregressive conditional heteroskedastic) models. Finally, the relationship between the economic uncertainty index and the BELEX sentiment index is examined to determine the nature of the dynamic correlation between these two variables. This may serve as an indication of the co-movement between economic and financial uncertainty in Serbia.

The rest of the chapter is structured as follows. Section 1 explains the concept of Thomson Reuters economic uncertainty index in general and then discusses the data for Serbia. Section 2 provides econometric results based on weekly and monthly aggregations of this economic uncertainty index. The analysis of the dynamic interdependence between the monthly data of the economic uncertainty index and the BELEX sentiment index in Serbia is presented in Section 3.

1. DESCRIPTION OF THOMSON REUTERS ECONOMIC UNCERTAINTY

Thomson Reuters MarketPsych Indices (TRMI) are based on sentiment analysis. The primary idea behind these indicators is to provide relevant and real-time information through the analysis of text content. The availability of such information is crucial for market participants, as it helps them to make more informed decisions.

The estimation of index values is based on three sets of content. The first group of indices is formed using only news data, the second group relies on social media data, while the third group combines both sources. This approach focuses on extracting meanings and relevant information from the sentences of the texts. For each sentence, the MarketPsych software identifies words from the MarketPsych lexicon, analyzes whether it has a positive or negative context, and determines whether it refers to the future, present, or past.¹⁷⁴ The MarketPsych lexicon is a large collection of both simple and complex English-language words and phrases.

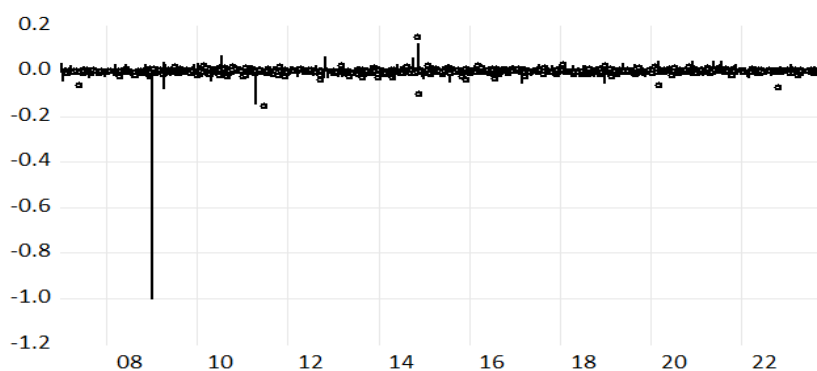
Our analysis is based on using Thomson Reuters economic uncertainty index for Serbia. The index values are derived from news references to uncertainty about business climate, net of references to confidence and certainty. Daily data are employed covering the period: 1/1/2007-10/31/2023. The index values range

¹⁷⁴ Peterson, R. L. (2016). *Trading on Sentiment: The Power of Minds Over Markets*. Hoboken: John Wiley & Sons.

between -1 and 1. Negative values suggest periods of uncertainty. If no relevant text is found, the index value is "NA", while a zero value means that the relevant text's sentiment cancel each other out.

The daily data on the Thomson Reuters economic uncertainty index are shown in Figure 1. On January 1, 2009, the index reached its minimum value which is -1. The result implies that the most significant episode of uncertainty coincides with the global financial crisis. The maximum index value was recorded on November 9, 2014, and it was 0.15. In November 2014, a three-year precautionary loan deal was reached with the International Monetary Fund, resolving months of uncertainty for the dinar currency.

Figure 1. The Thomson Reuters daily economic uncertainty index for Serbia



Source: LSEG Data & Analytics

Analysis of the index is challenging due to the absence of relevant text on certain days, causing the index values for those days to be treated as missing observations. Consequently, econometric analysis presented in sections 2 and 3 is based on weekly and monthly data that are created from daily data.

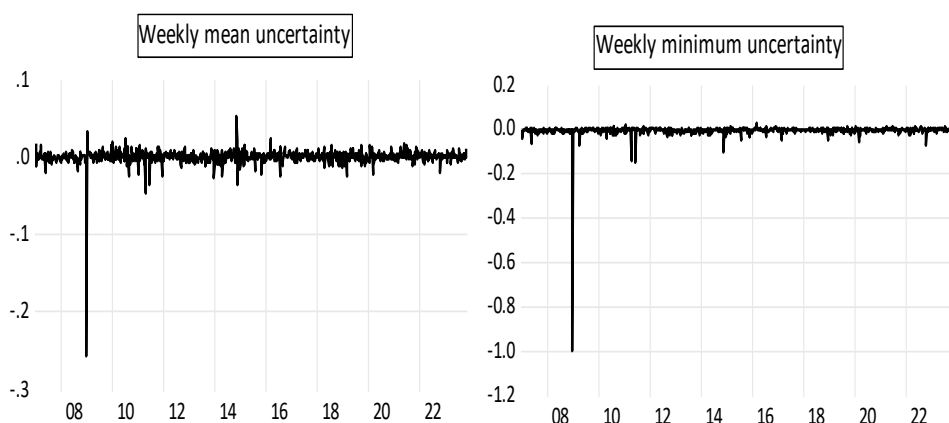
2. ECONOMETRIC TIME-SERIES ANALYSIS OF THOMSON REUTERS ECONOMIC UNCERTAINTY

Our econometric study has two objectives. The first objective is to identify extreme observations – additive outliers in the dynamic behaviour of the index of economic uncertainty. The second objective is to find the econometric specification that satisfactorily captures the main statistical properties of the economic uncertainty index. The econometric analysis is performed separately for weekly and monthly frequencies.

2.1. Weekly aggregation

Daily data are aggregated into weekly data using two approaches. The first approach defines the observation for a given week as the minimum value of the corresponding seven daily observations. The second approach is based on the sample mean of seven daily observations. In both cases, missing observations are interpolated by linear trend functions. The number of observations is 878. The two weekly series are shown in Figure 2.

Figure 2. The Thomson Reuters weekly economic uncertainty index for Serbia



Source: LSEG Data & Analytics and author's calculation

Weekly minimum data put weight on the negative daily values and therefore provide valuable information for tracking negative extreme events that have caused an increase in uncertainty.

The outliers are identified by applying various statistical techniques. Two of them recognise outliers by constructing intervals, and all data points that lie outside these intervals are marked as outliers. The Tukey method¹⁷⁵ uses the quartiles of the data to construct an interval, while the second method uses the mean and standard deviation of the data. In both methods, the width of the interval is influenced by a constant set by the researcher, which affects the sensitivity to outliers. A higher value leads to a wider interval and makes the methods less sensitive to outliers, while a lower value increases the sensitivity.

¹⁷⁵ Tukey, J. W. (1977). *Exploratory Data Analysis*. Massachusetts: Addison-Wesley.

The third method is based on wavelet analysis.¹⁷⁶ In this approach, a discrete wavelet transform is applied to the observed series, filtering the data and calculating the wavelet coefficients. High-pass and low-pass filters for the Haar wavelet are used to separate high-frequency and low-frequency content. The focus is on the wavelet coefficient with high-frequency content, as it is very sensitive to outliers. If the value of the wavelet coefficient exceeds the critical value, this method indicates the existence of an outlier. The last method is based on the detection of outliers in ARMA models.¹⁷⁷ Four different types of outliers are defined by their impact on the time series. The procedure for identifying outliers follows these steps: First, an ARMA model is estimated and the residuals are determined. Second, the impact of each type of outlier on the residuals is evaluated and standardized test statistics are calculated. If the highest test statistic exceeds the critical value, the corresponding outlier type is detected. By choosing the false discovery rate and the critical values, the researcher influences how sensitive the last two methods are to outliers.

The identification of outliers is based on a low sensitivity given the data frequency. Of the 20 outliers found, 19 indicate an increase in uncertainty due to their negative values. The most extreme negative values are extracted for the weeks that were associated with the following dates: 12/27/2008, 4/16/2011, 6/18/2011, 11/22/2014, 11/28/2015, 2/25/2017, 12/22/2018, 3/7/2020, and 10/22/2022.

The weekly average data is subjected to econometric modelling. We have opted for the time-changing conditional variability of GARCH form.¹⁷⁸ More precisely, power GARCH-in-mean¹⁷⁹, PGARCH(1,1)-M, is used under the assumption that an error term has a t-distribution. The power parameter is set to 1, so that conditional standard deviation is considered. The estimated model is presented in

¹⁷⁶ Bilen, C., & Huzurbazar, S. (2002). Wavelet-based detection of outliers in time series. *Journal of Computational and Graphical Statistics*, 11, pp. 311-327.

¹⁷⁷ Chen, C., & Liu, L. M. (1993). Joint estimation of model parameters and outlier effects in time series. *Journal of the American Statistical Association*, 88, pp. 284-297.

¹⁷⁸ Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 31, pp. 307-328.

¹⁷⁹ Ding, Z., Granger, C. W. J., & Engle, R. F. (1993). Long memory property of stock market returns and a new model. *Journal of Empirical Finance*, 1, pp. 83-106; Engle, R. F., Lilien, D. M., & Robins, R. P. (1987). Estimating time varying risk in the term structure: the ARCH-M model. *Econometrica*, 55, pp. 391-407.

Table 1. The BHHH algorithm¹⁸⁰ with Bollerslev-Wooldridge standard errors¹⁸¹ is employed.

Table 1. Estimated model for weekly mean economic uncertainty

Mean equation		
Variable	Estimate	z-statistic
Constant	0.002	68.87
GARCH	-0.258	-77.36
Volatility equation for standard deviation		
Variable	Estimate	z-statistic
Constant	0.003	41.25
ARCH(1)	0.216	22.75
GARCH(1)	0.383	56.42
t-distribution degrees of freedom	3.03	19.60
Diagnostic statistics: SC=-7.4386, Q(7)=1.57(0.98), Q(14)=4.59(0.99), Q ² (7)=1.60(0.98), Q ² (14)=19.60(0.14), ARCH1-14=18.96(0.17), Joint Statistic of the Nyblom test of stability:1.17.		

Note: The mean equation contains impulse dummy variable for the week that starts on December 27, 2008. Data were prewhitened prior to modelling.

Source: Author's calculation

The model performs well statistically. It shows significant temporal changes in the conditional standard deviation, represented by the absolute lagged shock (0.216) and the lagged own conditional standard deviation (0.383). The estimated standard deviation enters the mean equation with a negative estimate (-0.258), indicating that an increase in volatility causes a decrease in the level of the economic uncertainty index. This means that there is a tendency towards more bad news.

The estimated degree of freedom of the t-distribution is 3, which suggests the presence of heavy tails in the empirical distribution of the data. Such a shape of an empirical distribution is due to outliers that were previously discussed.

¹⁸⁰ Berndt, E., Hall, B., Hall, R., & Hausman, J. (1974). Estimation and inference in nonlinear structural models. *Annals of Economic and Social Measurement*, 3, pp. 653-666.

¹⁸¹ Bollerslev, T., & Wooldridge, J. M. (1992). Quasi-maximum likelihood estimation and inference in dynamic models with time-varying covariances. *Econometric Reviews*, 11, pp. 143-172.

2.2. Monthly aggregation

Using the similar approach of aggregation we have created two monthly series of uncertainties (202 observations). Upon correcting for the extreme dropdown at the beginning of 2009, we have searched for the outliers. Given that data are now of lower frequency, we opted for the medium criterion for outlier detections. The months for which extreme negative values were found are summarized in Table 2 below. They largely correspond to the weeks previously extracted.

Table 2. Negative outliers for monthly minimum uncertainty data

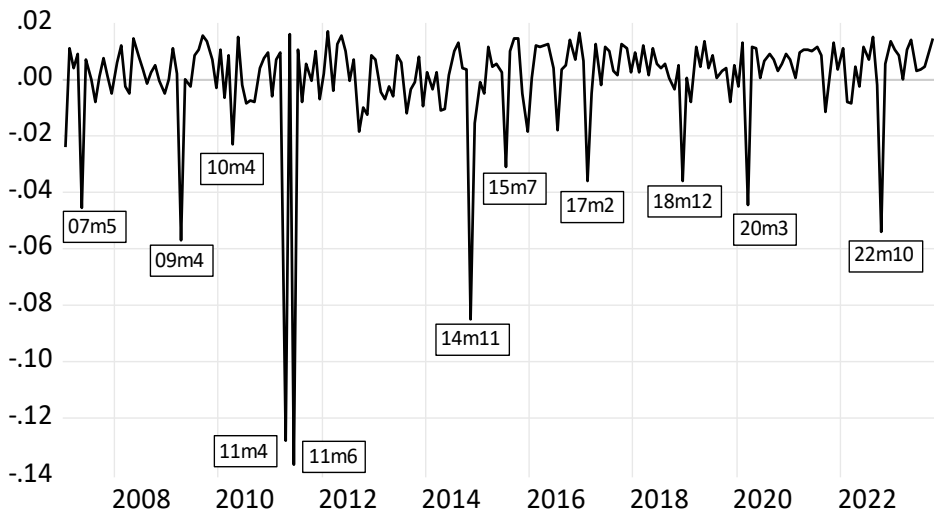
Month	Tukey	Mean/Std	Wavelet	Influence
2007m5	Y			
2009m1				Y
2009m4	Y	Y	Y	Y
2010m4	Y			
2011m4	Y	Y	Y	Y
2011m6	Y	Y	Y	Y
2014m11	Y	Y	Y	Y
2015m7	Y			
2017m2	Y			
2018m12	Y			
2020m3	Y			
2022m10	Y	Y		Y

Source: Author's calculation

All four methods indicate the presence of outliers in the following periods: April 2009, April and June 2011, and November 2014. The first outlier corresponds to the global financial crisis period. In the second quarter of 2011 there was a significant spike in global oil prices and a rise in food prices in Serbia that contributed to increased economic uncertainty. At the end of 2014, there was a significant drop in industrial output, driven mainly by a sharp fall in power production and mining. This result was due to severe floods in Serbia in May 2014. Only the Tukey method indicates an increase in uncertainty in March 2020, which coincides with the first wave of the COVID-19 pandemic. Three out of four methods detect an outlier in October 2022, which coincides with a surge in global energy prices and a sharp rise in inflation, triggered by the Russian invasion of Ukraine in early 2022.

Negative outliers found in the monthly minimum economic uncertainty index are noted in Figure 3.

Figure 3. Negative outliers detected in monthly minimum uncertainty index



Note: This graph represents a series corrected for the lowest value observed in January 2009. If the original data were used, other outliers would hardly be visible due to the extreme negative value of observation in January 2009.

Source: LSEG Data & Analytics and author's calculation

In an attempt to uncover the correlation structure of the data for the monthly mean index of economic uncertainty that we use in the econometric modelling, we calculated the sample ordinary and partial autocorrelation functions for the level values and the squared values. The results for the sample ordinary autocorrelation function presented in Table 3 show that the data do not exhibit a statistically significant pattern of dynamic correlation. However, the presence of outliers can produce a particular component that often overshadows the actual correlation pattern of the data. For this reason, we corrected the data for the presence of dominant outliers in the mean uncertainty index and recalculated the sample ordinary and partial autocorrelation functions. The new results are now substantially different (Table 4) and they indicate a significant individual autocorrelation for the first lag and a significant joint autocorrelation for the first four lags. The new results provided a clue to the structure of the moving average form in the mean equation. A further examination of the conditional variability showed the appropriateness of the ARCH(1) specification. The estimated model is presented in Table 5.

*Table 3. Sample ordinary autocorrelation function
for monthly mean uncertainty index*

lag	1	2	3	4	5	6
estimate	0.036	0.049	0.033	0.037	0.043	0.016
p-value of Q statistic	0.61	0.68	0.80	0.86	0.89	0.94
lag	7	8	9	10	11	12
estimate	-0.052	-0.021	0.005	-0.004	-0.040	-0.041
p-value of Q statistic	0.94	0.97	0.98	0.99	0.99	0.99

Note to Tables 3 and 4: The 95% confidence interval is [-0.138; 0.138].

Source: Author's calculation

*Table 4. Sample ordinary autocorrelation function
for monthly mean uncertainty index corrected for outliers*

lag	1	2	3	4	5	6
estimate	0.171	0.113	-0.009	0.014	-0.036	0.004
p-value of Q statistic	0.02	0.01	0.04	0.07	0.11	0.18
lag	7	8	9	10	11	12
estimate	0.055	0.068	0.091	-0.042	-0.053	0.013
p-value of Q statistic	0.22	0.23	0.20	0.24	0.27	0.35

Source: Author's calculation

Table 5. Estimated model for monthly mean economic uncertainty

Mean equation		
Variable	Estimate	z-statistic
Constant	-0.0008	-3.35
MA(1)	0.262	3.36
MA(2)	0.149	2.25
Volatility equation		
Variable	Estimate	z-statistic
Constant	4.08E-06	6.42
ARCH(1)	0.171	2.08
Diagnostic statistics: SC=-8.825, Q(6)=1.63(0.80), Q(12)=5.19(0.88), Q ² (6)=3.41(0.76), Q ² (12)=11.69(0.47), ARCH1-6=2.99 (0.81), Joint Statistic of the Nyblom test of stability: 2.13.		

Note: The mean equation contains impulse dummy variables for the following months: 2009m1, 2011m4, 2011m6, 2014m4, 2014m11, 2015m3, 2021m7, 2021m11.

BHHH algorithm with Bollerslev-Wooldridge standard errors is used.

Source: Author's calculation

The monthly mean uncertainty index is also characterized by a changing volatility, which is now well captured by only one variable, the lagged squared shock (0.171). The mean equation contains moving average components of order one and two and thus shows a dynamic structure with short memory. Such a structure could not be found if we neglected the additive outliers.

3. CO-MOVEMENT WITH THE BELEX SENTIMENT INDEX

Numerous studies have examined the link between economic uncertainty and financial markets, yet the empirical evidence remains inconclusive. On the one hand, rising uncertainty about economic conditions can make investors worry about future profits or potential changes in interest rates, which can cause stock prices to fall.¹⁸² On the other hand, a decline in stock prices may indicate that investors are losing faith in both the stock market and the economy. This can lead to reduced business investment and production, increasing economic uncertainty.¹⁸³ One of the objectives of the chapter is to examine the relationship between economic uncertainty and the financial market in Serbia. BELEX sentiment index is used as financial market indicator.

3.1. Explanation of the BELEX sentiment index

BELEX sentiment index is formed to capture the predictions of market participants about financial market trends in Serbia. Tracking index movement is crucial for making informed investment decisions, as it helps investors to anticipate market changes and adjust their strategies. This monthly indicator is constructed by Belgrade Stock Exchange.¹⁸⁴

BELEX sentiment index is based on the votes of the following three groups of voters: Stock Exchange members, portfolio managers of investment and voluntary pension funds, and users of the Belgrade Stock Exchange official site. Participants can select one of seven categories that best represents their forecast

¹⁸² Li, X. L., Balcilar, M., Gupta, R., & Chang, T. (2016). The causal relationship between economic policy uncertainty and stock returns in China and India: Evidence from a bootstrap rolling window approach. *Emerging Markets Finance and Trade*, 52, pp. 674-689.

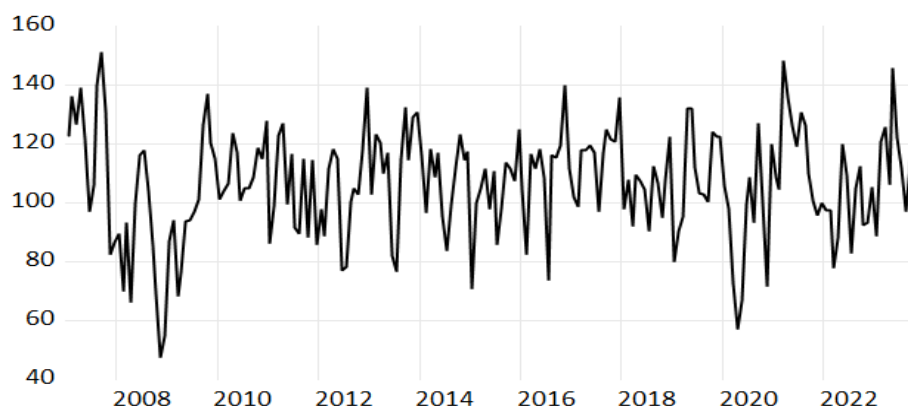
¹⁸³ Chang, T., Chen, W. Y., Gupta, R., & Nguyen, D. K. (2015). Are stock prices related to the political uncertainty index in OECD countries? Evidence from the bootstrap panel causality test. *Economic Systems*, 39, pp. 288-300.

¹⁸⁴ <https://www.belex.rs>

for the market trends in the next month, including strong fall, moderate fall, slight fall, stagnation, slight rise, moderate rise, and strong rise.¹⁸⁵

The base value of the index is 100 points, and its value can vary from 0 to 200 points. If the index value is less than 100, it suggests negative market expectations, whereas a value greater than 100 reflects positive market sentiment. The monthly data on BELEX sentiment index from January 2007 to October 2023 are shown in Figure 4. The lowest index values were recorded during the global financial crisis (the end of 2008) and the first wave of the COVID-19 pandemic (the beginning of 2020).

Figure 4. BELEX sentiment index



Source: Belgrade Stock Exchange

3.2. Dynamic relation between the BELEX sentiment index and economic uncertainty index

Economic uncertainty can be linked to the risk associated with unpredictable future economic policy and regulatory environments. We want to find out how this uncertainty is related to the BELEX sentiment index, which serves as an indicator of market participants' perceptions of future movements in the financial markets.

The characteristics of the dynamic relationship between economic uncertainty and the BELEX sentiment index are assessed on a monthly basis by applying standard and time-varying Granger causality tests. The values of the BELEX sentiment index are standardized prior to modelling.

¹⁸⁵ https://www.belex.rs/files/e_trgovanje/BELEXsentiment-site-english.pdf

The conventional Granger test shows that there is no causality in either direction. To get a better insight into the interdependencies, we used the recently introduced time-varying Granger causality test.¹⁸⁶

Three versions of the test were developed based on recursive estimation, and their limiting distributions are derived.¹⁸⁷ These are: forward expanding, rolling and recursive evolving windows. All tests are calculated as Wald tests, but with differently generated subsamples. An algorithm to control heteroscedastic-consistent sequences is also developed. The simulation results show that the performance of the recursive evolving window tests is better than that of the other two tests in small samples.

The significant causality is only found in one direction, namely from the BELEX sentiment index to the index of economic uncertainty (see Figure 5). This causality is confirmed by two tests that show significance for the most part of the sample - from the end of 2016. Causality in the opposite direction, running from the economic uncertainty index, is not found (Figure 6). The figures presented are from the VAR model based on the window of size 72. The results are robust to a change in the window size.

One could argue that the standard VAR model does not provide an adequate framework for capturing the specific characteristics of the time series under consideration, given the way they are computed, the presence of numerous additive outliers and the changing variability. For this reason, we estimated the Markov-Switching VAR model (MS-VAR)¹⁸⁸ under the assumption that the error covariance matrix and the effects of the lagged explanatory variables vary between the two regimes. The BHHH algorithm is applied. It is estimated that the average constant duration of regime 1 is about 3 months and about 2 months in regime 2. The probability of remaining in regime 1 while in this regime is estimated to be 0.70. The probability of remaining in regime 2 when already in this regime is estimated at 0.55.

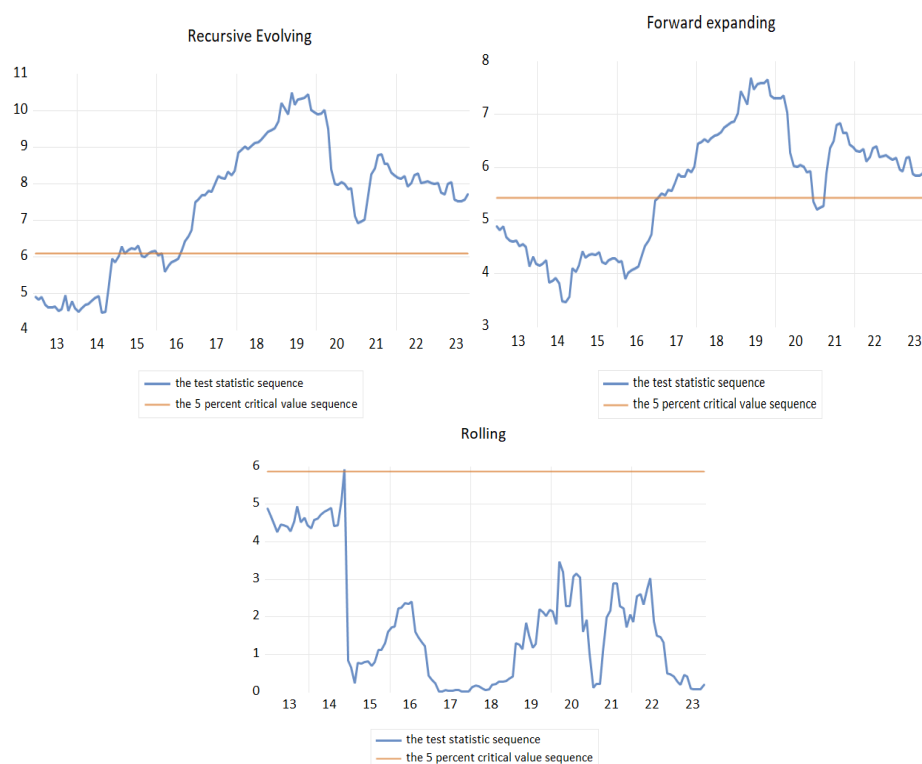
¹⁸⁶ Shi, S., Hurn, S., & Phillips, P. C. B. (2020). Causal Change Detection in Possibly Integrated Systems: Revisiting the Money-Income Relationship? *Journal of Financial Econometrics*, 18, pp. 158-180.

¹⁸⁷ Ibid.

¹⁸⁸ Krolzig, H. M. (1997). *The Markov-Switching Vector Autoregressions*. New York: Springer.

The calculated variance decomposition of the forecast error from the estimated MS-VAR model after 12 months, based on the order: BELEX Sentiment - economic uncertainty, shows that in regime 1, each variable is predominantly explained by its own unexpected shocks and that the same is true for the BELEX sentiment index in regime 2. However, about 46% of the variability of the economic uncertainty index can be attributed to the unexpected shocks of the BELEX sentiment index in regime 2. The results are relatively robust to a reversed ordering of the variables.

Figure 5. Time-varying Granger causality from BELEX sentiment to economic uncertainty



Source: Author's calculation

Figure 6. Time-varying Granger causality from economic uncertainty to BELEX sentiment



Source: Author's calculation

In addition to insurance risks associated with the types of insurance that insurers deal with, as well as certain extreme factors (risk of insurance premiums, risk of reserves, risk of insured behaviour, etc.), credit and operational risks, market risks are also important for insurers. These risks (interest rate risk, foreign exchange risk, etc.) are easier to measure than insurance risks thanks to the availability of high frequency data from the financial markets and the application of financial and econometric models that can be employed to model these risks. In this context, our econometric results based on the analysis of the time series properties of Thomson Reuters economic uncertainty index in Serbia can provide valuable information and insights.

Chapter 8.

ECONOMIC PRECONDITIONS FOR THE MODERNISATION OF INSURANCE

The modernisation of insurance is a complex and multidimensional process that includes technological transformation, improvement in risk assessment and prediction, increased cost efficiency, customisation of insurance products and services to meet contemporary customer needs, as well as enhancement of the regulatory framework. This process is driven by changes in the economic, social, and natural environment and is enabled by technological innovations and regulatory reforms. Key economic factors that encourage the modernisation of insurance include: the growth of real income, increased propensity to save, higher returns on insurance premiums, long-term macroeconomic stability, institutional improvements, and accelerated technological development. These factors contribute to creating a stimulating environment for the modernisation of the insurance sector. It is important to emphasise that modernisation is closely linked to the development of insurance. Namely, the factors that drive the growth and expansion of insurance simultaneously influence its modernisation, thereby ensuring greater competitiveness, better customer protection, and a more efficient response to contemporary market challenges.

The advancement of the economy increases the real value of income and assets, thereby enhancing both the capacity and the need for insurance services. Growth in real income above the subsistence minimum creates room for an increase in all forms of long-term savings, including insurance services. As the economy grows, the real value of average income reaches a level at which the income elasticity of demand for insurance services exceeds 1. According to the World Bank classification, Serbia is at the upper limit of the middle-income countries, which implies that the average income of citizens falls within the range where the income elasticity of demand for insurance is greater than 1. Similarly, the growth in the real value of assets per capita increases demand for insurance services. The propensity to save, including investment in insurance, increases with rising income but also depends on a number of other factors, such as the return on savings, macroeconomic stability, the quality of institutions, and the population's value system. An increase in returns on insurance premiums has some influence on the willingness to purchase insurance, although empirical research suggests that this is not a decisive factor in the growth of insurance. The underdevelopment of Serbia's financial market directs insurance companies toward investments in government securities and other low-yielding assets. Therefore, expanding

investment opportunities into higher-yielding assets would stimulate the growth and modernisation of the insurance sector. Sustained macroeconomic stability—primarily low and stable inflation, along with relative exchange rate stability—is essential for insurance, as a form of long-term savings, to successfully transfer income from the present to the future and preserve its real value. Over the past two and a half decades, Serbia has made progress in establishing macroeconomic stability, but strong memories of prolonged high inflation and two episodes of hyperinflation still deter people from long-term saving and reduce demand for insurance services.

Institutional improvement involves enhancing the quality of legislation and ensuring its consistent and efficient implementation. Serbia ranks 93rd in the world in terms of regulatory quality, and 104th in terms of the rule of law, that is, consistency in the application of regulations—an extremely poor position for a European country. Therefore, in order to achieve economic and social progress, as well as to develop and modernise the insurance sector, it is essential to improve the quality of regulations and ensure their consistent enforcement. In addition to laws and regulations, economic behaviour is significantly influenced by customs, traditions, and the value system of citizens. From the perspective of insurance, it is relevant that Serbian citizens predominantly exhibit short-term orientation, which negatively affects their willingness to engage in long-term saving, including investment in insurance. This short-term orientation is a consequence of historical legacy, which includes frequent wars, sanctions, deep internal political divisions and conflicts, violations of property rights, hyperinflation, and other crises, all of which have led people to focus on short-term survival.

A gradual shift toward long-term orientation among citizens requires a prolonged period of social and economic stability, along with economic incentives and public education. Technological advancement, especially in the field of information technology, enables more accurate risk prediction, lower costs, better customisation of insurance products to user needs, and more. Serbia ranks slightly higher in its ability to adopt advanced technologies than in its overall level of development, which indicates that the current state of technology is not an obstacle to the country's economic progress, including the modernisation of the insurance sector.

Social changes such as increased life expectancy and modest public pensions are driving the need for private pensions and life insurance. At the same time, the shift from multigenerational households to nuclear families—consisting of spouses and minor children—reduces the potential for intra-family financial support, further reinforcing the importance of insurance. In terms of demographic characteristics—an ageing population and the predominance of nuclear families—Serbia increasingly resembles developed countries, which should

contribute to growing demand for insurance services. Additionally, improvements in educational attainment and the rising share of the population living in urban areas have a positive effect on the development of the insurance sector. The growth of real income, combined with limited access to certain services in the public healthcare system and the expansion of private healthcare, further boosts the demand for private health insurance.

Climate change is also becoming a significant factor. The increased frequency of extreme weather events, such as floods, storms, and droughts, causes damage to property, disrupts economic activity, and negatively affects human health, thus increasing the need for property, life, and health insurance. According to climate models, Serbia is located in a region of the world that is expected to be disproportionately affected by climate change, which presents a major challenge not only for insurance companies but also for the state and policyholders. The following analysis will focus on the economic, institutional, and technological factors of insurance sector modernisation, while the impact of demographic factors and climate change will not be the subject of further discussion.

1. GROWTH OF REAL INCOME AND INCREASED PROPENSITY TO SAVE

Per capita real income represents a fundamental determinant of the demand for insurance services. Cross-sectional data show that more developed countries have a higher share of insurance premiums in GDP compared to less developed countries. This indicates that, in the long run, insurance services grow faster than GDP, meaning they have an income elasticity of demand greater than 1. Most empirical studies¹⁸⁹ find that the relationship between insurance premiums and real GDP per capita follows an S-curve. This means that the income elasticity of demand varies with changes in real income – at low income levels, elasticity is low; it increases at middle levels of development, and then decreases at high income levels¹⁹⁰. In studies based on time series using threshold models, it was found that the income elasticity of demand for insurance services is less than 1, but the

¹⁸⁹ Carter, R. L., & Dickinson, G. M. (1992). *Obstacles to the liberalization of trade in insurance*. London: Trade Policy Research Centre, Harvester Wheatsheaf; Enz, R. (2000). The S-curve relation between per-capita income and insurance penetration. *The Geneva Papers on Risk and Insurance-Issues and Practice*, 25, pp. 396-406; Wei, Z., Liu, Y., & Dickinson, G. (2008). The Chinese insurance market: Estimating its long-term growth and size. *The Geneva Papers on Risk and Insurance. Issues and Practice*, 33(3), pp. 489-506.

¹⁹⁰ Lee, C. C., & Chiu, Y. B. (2012). The impact of real income on insurance premiums: Evidence from panel data. *International Review of Economics & Finance*, 21(1), pp. 246-260.

elasticity of demand for life insurance increases with rising income¹⁹¹. Based on data covering the period from 1850 to 2020, the relationship between insurance premiums and income is best described by a curve with two peaks, reflecting periods of high income elasticity of demand for insurance services. The first peak corresponds to the late 19th century, when the demand for life insurance increased as a means of protecting families from the financial risk of the premature death of the breadwinner. The second peak refers to the late 20th century, when the demand for insurance increased as a form of long-term saving.

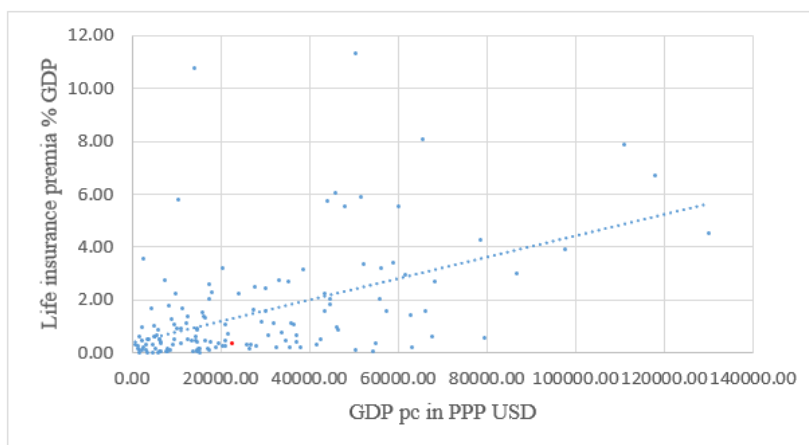
Based on a sample of around 150 countries and using cross-sectional data, Figures 1 and 2 confirm the positive relationship between the share of insurance premiums in GDP and real GDP per capita, measured in purchasing power parity (PPP) dollars. This positive relationship between the share of insurance premiums in GDP and a country's level of development confirms that the income elasticity of demand for insurance services is greater than 1 in the long run. The slope of the line indicating the increase in the share of insurance premiums with rising GDP per capita is not steep, which leads to the conclusion that, on average, insurance premiums grow only slightly faster than GDP in the long run. This finding is consistent with empirical research in which the relationship between insurance premiums and income is described by an S-curve or a curve with peaks, implying that the income elasticity of demand for insurance varies over time but is generally greater than 1 in the long run. However, there are also income levels where the elasticity coefficient is less than 1. The development of life insurance in Serbia, measured by the share of insurance premiums in GDP, is below the level corresponding to Serbia's stage of development (Figure 1), while the development of non-life insurance is above what would be expected for a country at Serbia's level of economic development (Figure 2).

Figures 1 and 2 show that at a given level of economic development, there is a relatively large dispersion in the share of insurance premiums in GDP. This suggests that, in addition to a country's level of economic development, other factors also influence the demand for insurance¹⁹².

¹⁹¹ Kohl, S., & Römer, M. (2024). Insurance demand: a historical long-run perspective (1850–2020). *The Geneva Papers on Risk and Insurance - Issues and Practice*, pp. 1-24, <https://doi.org/10.1057/s41288-024-00339-8>

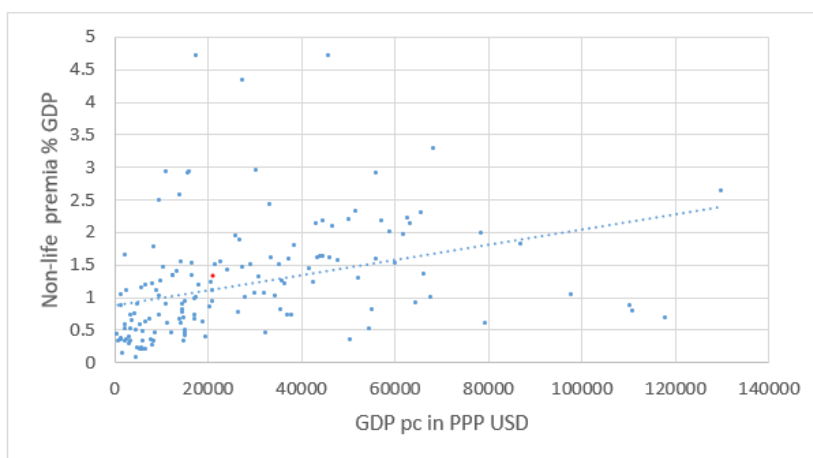
¹⁹² Arsić, M. (2024). Long-term determinants of insurance development in CEE countries. In: *Transformation of the insurance market: Responses to new challenges*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 47-76.

Figure 1. Real GDP per capita and life insurance premiums by country, 2018–2020



Source: World Bank Database

Figure 2. Real GDP per capita and non-life insurance premiums by country, 2018–2020



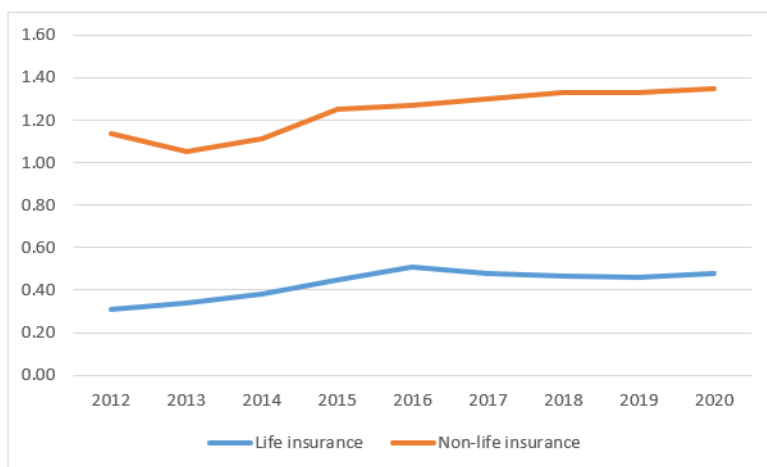
Source: World Bank Database

The low level of development of life insurance in Serbia can largely be attributed to non-economic factors such as the dominant short-term orientation of Serbian citizens, low trust in institutions, and limited public awareness of the benefits of life insurance. Expanding tax incentives could potentially support the development of life insurance, but this effect is unlikely to be strong. This is evidenced by the stagnation of private pension insurance in Serbia despite the existence of tax incentives. For life insurance to grow, an increase in real incomes

in the coming years is essential, along with broader social and economic stability. Additionally, the development of life insurance could be further encouraged through better public education and communication about how life insurance works, its advantages, and related benefits.

The share of life and non-life insurance premiums in Serbia's GDP increased slightly during the period 2012–2020, but it remains significantly lower than in most European countries. Non-life insurance premiums, with the exception of 2013, show a slow but steady increase in their share of GDP, while life insurance premiums have stagnated since 2016 (Figure 3). When analysing the share of insurance premiums in GDP, it is important to note that Serbia's GDP stagnated during the 2012–2016 period and experienced relatively strong growth afterwards. This implies that despite the stagnation of life insurance premiums relative to GDP, their real value has increased since 2016.

Figure 3. Insurance premiums in Serbia as a percentage of GDP (2012–2020)



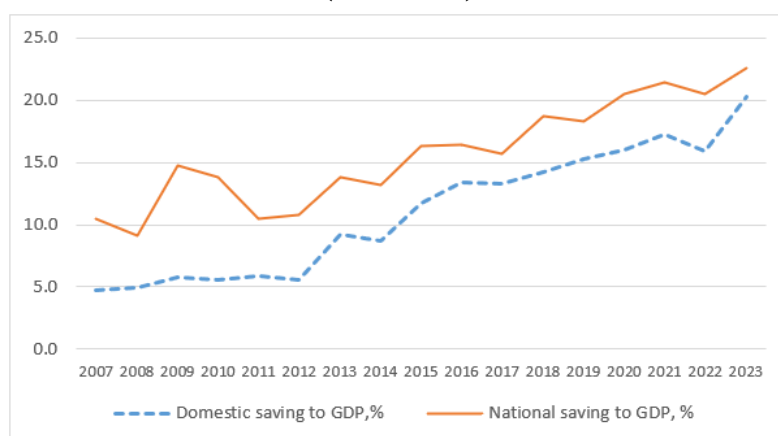
Source: World Bank Database

Insurance represents a form of long-term savings, and as such, the propensity of citizens to engage in insurance is closely linked to their inclination toward saving. Empirical research has shown that by the end of the 20th century, long-term savings became the main driver of insurance development in developed countries¹⁹³. Domestic savings encompass household, corporate, and government savings within a country's territory, and in Serbia, this has historically been at a low level. However, over the past two decades, domestic savings have

¹⁹³ Kohl & Römer (2024), op. cit.

increased several times over, currently standing at around 20% of GDP (Figure 4). This growth can be attributed to the rise in real income and the strengthening of macroeconomic stability, particularly the stabilisation of inflation at low levels and the stability of the dinar exchange rate. The significant increase in domestic savings has been driven by the growth in government savings, as the difference between public investments and the fiscal deficit has been positive for the past decade.

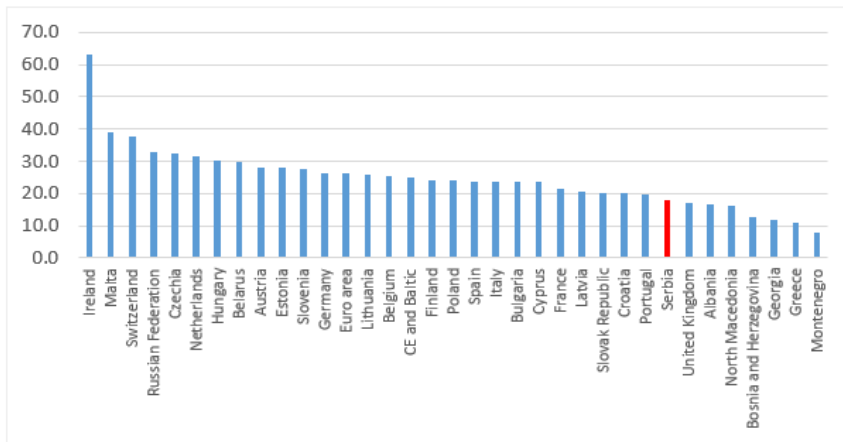
Figure 4. Domestic and national saving as a percentage of GDP in Serbia (2012–2020)



Source: World Bank Database

Although domestic savings in Serbia have increased significantly over the past two decades, Serbia is still in the group of European countries with low savings, which is inadequate for a country that aims to catch up with Central and Western European countries in terms of development. Given that outflows of income from capital to abroad (interest, dividends) are approximately equal to the inflows of income from abroad (remittances, pensions, etc.), and that lower foreign direct investment is expected due to rising business costs in Serbia, financing investments in Serbia will increasingly depend on domestic savings. Therefore, the growth of domestic savings is a condition for maintaining high levels of investment, which is a necessary condition for catching up with Central and Western Europe in terms of development. Based on historical data, domestic savings in Serbia were at a low level throughout most of the 20th century, except in the early decades of socialism when high domestic savings were achieved through compulsory measures.

Figure 5. Domestic savings as a percentage of GDP (2021–2023)



Source: Eurostat

Household savings in all countries represent an important component of total domestic savings. The population, as a sector, is generally a net saver, meaning that its savings are used to finance the economy and the government. In economic theory, there are several theories¹⁹⁴ that explain how decisions about consumption and savings are made at the household level, among which the most influential are: the Life-Cycle Hypothesis¹⁹⁵, the Permanent Income Hypothesis¹⁹⁶, Keynesian Theory¹⁹⁷, Precautionary Saving¹⁹⁸, Ricardian Equivalence¹⁹⁹, and others. These theories differ in their assumptions about how people make decisions regarding savings and consumption, whether they are impulsive or think long-term, whether they can accurately predict future circumstances, how much they consider the well-being of future generations, and so on.

¹⁹⁴ Browning, M., & Annamaria, L. (1996). Household Saving: Micro Theories and Micro Facts. *Journal of Economic Literature*, 34(4), pp. 1797-1855.

¹⁹⁵ Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In: *Post Keynesian economics*, Kurihara, K. K. (ed.), New Brunswick, NJ: Rutgers University Press.

¹⁹⁶ Friedman, M. (1957). *A Theory of the Consumption Function*. Princeton: Princeton University Press.

¹⁹⁷ Keynes, J. M. (1936). *The general theory of employment, interest, and money*. London, UK: Macmillan

¹⁹⁸ Alba, L., Bande, R., & Riveiro, D. (2017). Precautionary Saving: a review of the theory and the evidence. *MPRA Paper*, No. 77511, University Library of Munich

¹⁹⁹ Barro, R. J. (1974). Are Government Bonds Net Wealth? *Journal of Political Economy*, 81, pp. 1095-1117.

The Life-Cycle Hypothesis is the dominant and theoretically best-developed theory of household savings, according to which savings in period t depend on income in period t , the assets the household possesses in period t (the sum of saved income from the past), and expected future income. According to this theory, people are capable of accurately predicting future income, and they perform long-term optimisation of consumption and savings, aiming to maximise consumption over their lifetime while minimising large variations in consumption over time.

Although the Life-Cycle Hypothesis has solid empirical support, there are deviations in people's behaviour from its theoretical predictions. Poor households, whose income is at the level of the subsistence minimum (liquidity-constrained households), are unable to perform dynamic optimization of consumption and savings, even if they wish to. Such households account for 20-40% of the population in developed countries, while their percentage is higher in less developed countries²⁰⁰. Additionally, according to the Life-Cycle Hypothesis, households make decisions with the goal of maximizing consumption throughout their lifetime, without considering how much wealth they will leave as an inheritance or how their descendants will live. However, there are arguments that some households are equally concerned about the well-being of their heirs as they are about their own well-being, which leads them to want to leave as much wealth as possible as an inheritance²⁰¹. The existence of liquidity-constrained households negatively affects savings, while the intention of households to leave as much wealth as possible to their heirs increases savings.

The Life-Cycle Hypothesis has relevant predictions regarding household behaviour in decision-making about savings and consumption in terms of life and private pension insurance. According to this theory, individuals are motivated to engage in life insurance programs to protect their families from poverty in the event of premature death, but also to save for old age or major investments, such as purchasing a home or financing children's education. According to this theory, individuals are also motivated to contribute to private pension insurance to prevent a significant decline in living standards when they retire. This motivation is particularly relevant given that the average pension in countries applying the Bismarck model of public pension insurance in Continental Europe typically amounts to 40-50% of average wages in those countries, while in countries that apply the Beveridge system of public pension insurance, average pensions are

²⁰⁰ Diogo, S. (2022). Liquidity constraints and fiscal multipliers. *MPRA Paper*, No. 112132, University Library of Munich

²⁰¹ Bernheim, B. D., Shleifer, A., & Summers, L. H. (1985). The Strategic Bequest Motive. *Journal of Political Economy*, 93(6), pp. 1045-76.

around 25-30% of average wages. Demographic changes, such as the increased number of years people spend as retirees, and the decreasing ability of elderly people to rely on the support of their descendants, further strengthen the need for savings for old age. Although there is evidence that people's needs decrease with age, it is still quite certain that most people whose public pension is their only source of income in old age will face a significant decline in their standard of living. In such circumstances, investing in various forms of long-term savings (life and pension insurance, investments in real estate and securities, bank savings, etc.) represents a way for individuals and households to prevent a significant decline in their standard of living after retirement.

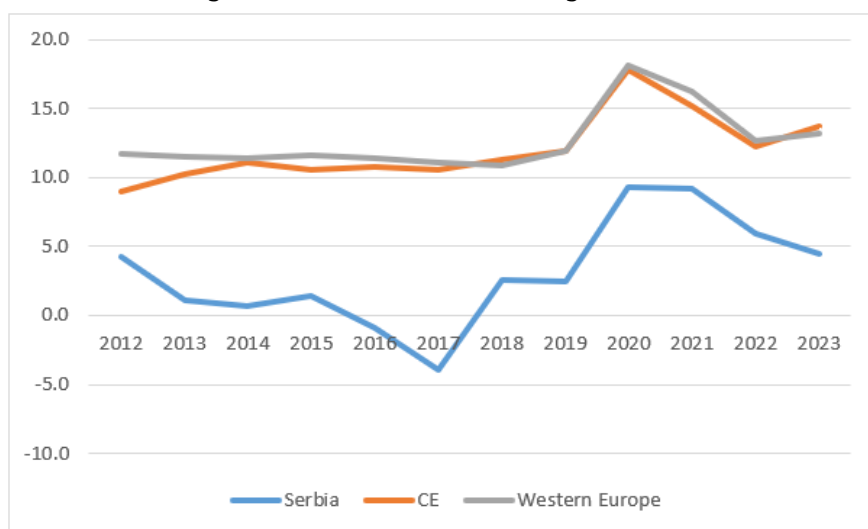
Gross household savings in Serbia, which include insurance premium payments, have been at a low level over the long term, significantly lower than in countries in Western, Central, and Eastern Europe (see Figure 6). Moreover, household savings over the previous 12 years have varied significantly. The savings rate²⁰² at the beginning of the observed period was about 5%, but in the following five years, it decreased, becoming negative in 2017, which can be explained by the stagnation of real wages and the decline in the real value of pensions during this period. After 2017, household savings experienced significant growth, with the savings rate reaching nearly 10% in 2020 and 2021. The spike in the savings rate during the COVID-19 pandemic was temporary and directly caused by the inability to spend due to epidemiological restrictions. After the end of the COVID-19 pandemic, the savings rate in Serbia dropped, currently standing at around 5%. The household savings rate in Serbia is significantly lower than in the old EU member states, where the rate averaged 13.6% in 2023, and also lower than in Central European countries, where the rate averaged 12.5%.

Thus, the relevant question is: What are the reasons for the low savings rate of households in Serbia compared to other European countries? The first reason is that real incomes in Serbia are still lower than in EU countries, including the least developed ones like Bulgaria and Romania. Low real incomes in Serbia imply that the percentage of liquidity-constrained households, whose incomes are at or just above the subsistence minimum, is higher than in other European countries²⁰³.

²⁰² The savings rate is defined as the ratio of gross savings to disposable income, multiplied by 100.

²⁰³ The savings rate in other Western Balkan countries is likely similar to or slightly lower than in Serbia, but there are no internationally comparable data for them.

Figure 6. Gross household saving rate, in %



Note: The gross saving rate of households is defined as gross saving divided by gross disposable income, with the latter being adjusted for the change in pension entitlements.

Source: Eurostat Database

The second reason for the lower household savings rate is that households in Serbia engage in long-term optimization of consumption to a lesser extent compared to households in other countries, including those at a similar level of development. The reasons for this could be the long periods of macroeconomic and political instability that Serbia has gone through, as well as weak institutions that generate non-commercial risks affecting savings (see the chapter on institutions and culture). Serbia has gone through periods of high inflation, large devaluations of the dinar, which have largely or even completely devalued savings. Additionally, wars and internal political crises discourage people from thinking long-term, and thus from saving. Finally, weak institutions create distrust among citizens towards the state, which also discourages savings.

From the above, it follows that further growth of real incomes and a decrease in the percentage of liquidity-constrained households are key conditions for the growth of the household savings rate, and thus for the growth of insurance investments. In addition to this, it is necessary to successfully maintain macroeconomic stability over a long period, improve political relations between the countries of the region, stabilize the political situation in the country, and increase the competence and efficiency of institutions.

2. INCREASE IN RETURNS ON INSURANCE PREMIUMS

Demand for insurance services, in addition to real income, also depends on the returns achieved by insurance companies through investments of the premiums paid by policyholders. Insurance companies, as conservative investors, prioritise security over returns, and thus allocate a larger portion of their funds to government securities. However, in developed countries, a significant portion of insurance companies' funds is invested in prime corporate securities (bonds and stocks) to increase the average rate of return. Investing part of the funds in corporate securities requires high analytical capacities within insurance companies to ensure that the growth in expected returns does not lead to a significant increase in risk.

In developed countries, insurance companies invest a relatively large percentage of their funds in corporate bonds and stocks, while a small portion is invested in real estate, cash, and deposits. In contrast, insurance companies in Serbia do not invest in corporate bonds, as they do not exist, and investments in stocks are minimal due to sporadic stock trading on the Belgrade Stock Exchange and questionable stock quality. More than half of the funds of insurance companies in Serbia are invested in government securities, and a significant portion of assets are invested in non-earning (cash) or low-return assets (deposits, real estate).

The capital market in Serbia is largely underdeveloped, which affects investment opportunities, especially for specialized investors like insurance companies. These companies, which would typically be interested in stable, long-term investments in stocks and bonds, have limited options due to the underdevelopment of the capital market. The capital market in Serbia has gone through periodic fluctuations. After initial stagnation in the 1990s, the market experienced expansion in the early 2000s, with the privatisation of companies playing a key role. However, this expansion was not stable, and the capital market lost value after 2007, when it reached a peak of 65.9% of GDP²⁰⁴. In 2022, Serbia's market capitalisation was only 4.8% of GDP, which is a very low level²⁰⁵. This is significantly lower compared to more developed markets, suggesting that investment opportunities, such as investments in stocks, are limited. Insurance companies, which invest large amounts of capital, face a shortage of choices and opportunities to diversify their investments in the domestic market.

²⁰⁴ Worldbank Database

²⁰⁵ TheGlobalEconomy.com and the Belgrade Stock Exchange

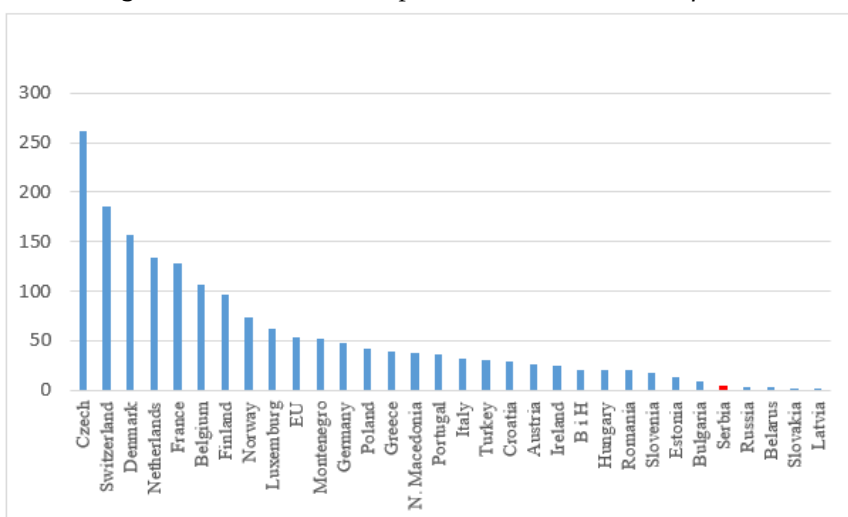
*Table 1. Investment portfolio of the insurance companies in 2018, in %**

	Eurozone	United States	Spain	Serbia
Corporate fixed income	31.4	51.5	21.8	-
Sovereign fixed income	34.5	13.6	56.9	53.0
Equity	13.9	13.1	6.0	0.2
Loans	5.2	10.6	1.0	10.2
Cash and deposits	4.6	3.9	7.8	10.3
Real estate	2.3	0.6	2.5	7.7
Other investments	8.2	6.7	4.0	18.6

* Serbian data from 2023.

Source: MAPFRE Economic Research (2020), for Eurozone, US and Spain and NBS for Serbia.

Figure 7. Stock market capitalisation in 2022, % of GDP



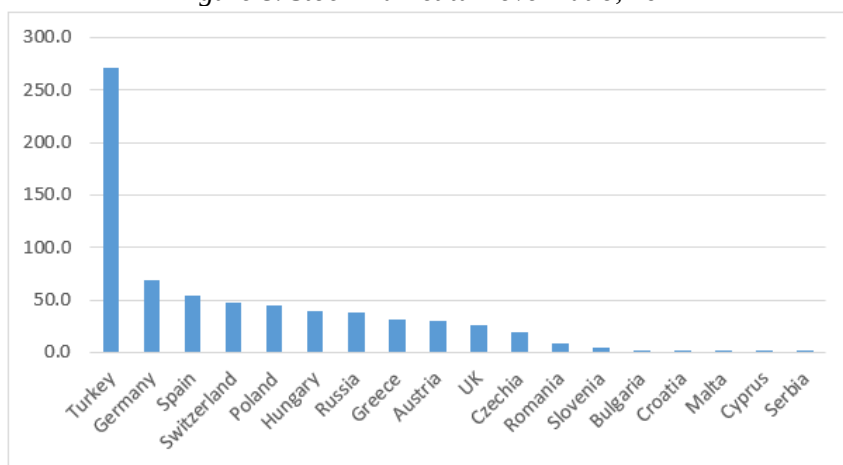
Source: TheGlobalEconomy.com and the Belgrade Stock Exchange

In addition to the low value of equity securities on the Belgrade Stock Exchange, another significant problem is that most shares are not actively traded. In 2022, the stock market turnover ratio, which represents the ratio of share trading volume to market capitalisation, amounted to just 0.1% in Serbia, placing the country at the bottom among European countries for which data is available (Figure 8). The near-total absence of share trading is due to the fact that shares were issued on the stock exchange as a result of legal provisions regulating privatization, rather

than for the purpose of raising additional capital for companies. As a result, in most cases, trading in securities ceased once ownership became concentrated²⁰⁶.

The underdevelopment of the financial market is a limiting factor for the modernization and development of insurance companies in Serbia. Table 1 shows that insurance companies in Serbia invest almost their entire portfolio in low-yield assets, such as government securities, real estate, deposits, etc. Insurance companies in countries with developed financial markets balance between safe investments (government bonds, real estate, deposits) and riskier ones (equities, corporate bonds) in order to achieve higher returns, while this kind of portfolio optimization is not available to insurance companies in Serbia. The development of the financial market is one of the key conditions for increasing returns on the assets of insurance companies.

Figure 8. Stock market turnover ratio, 2022



3. MACROECONOMIC STABILITY

Although the interest rate on savings does have an impact on the level of savings, empirical research suggests that this influence is small, and in some studies, it is found to be statistically insignificant²⁰⁷. The explanation for these results is that

²⁰⁶ The reasons for the low market capitalisation and low trading volume on the Belgrade Stock Exchange, as well as potential measures for revitalising the capital market, are thoroughly analysed in: Šoškić, D. (2025). Tržište kapitala kao faktor rasta investicija i privrednog razvoja u Srbiji. *SANU Proceedings*, forthcoming

²⁰⁷ Bernheim, B. D. (2002). Taxation and Saving. In: *Handbook of Public Economics*, Vol. 3, Auerbach, A. J., & Feldstein, M. (eds.), Elsevier, pp. 1173-1249.

most households save primarily to transfer current income into the future with the goal of smoothing consumption over their lifetime, while the return on savings is a secondary consideration. Of course, investors—whose primary concern is the rate of return—are an exception, but they make up a small portion of the overall population.

Given that, for most households, the key motivation for saving is to transfer income from the present to the future, it is crucial for them that the real value of their savings is not eroded by high inflation or depreciation of the national currency. From this, it can be concluded that, in order to increase savings, it is important to maintain long-term macroeconomic stability in the country and for citizens to have confidence that such stability will persist in the future. Since citizens make saving decisions based on long-term macroeconomic stability, this analysis will examine inflation trends and exchange rate stability in Serbia over the past several decades.

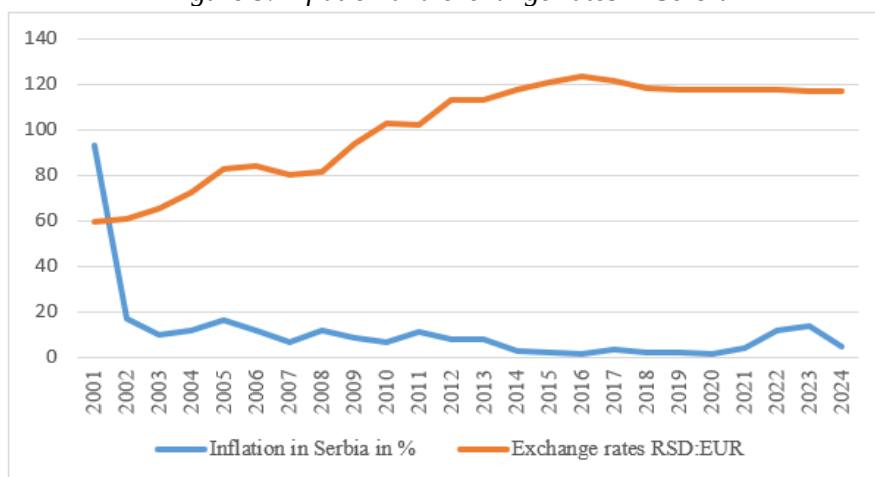
Serbia, as part of Yugoslavia, went through a period of high inflation and two episodes of hyperinflation during the 1980s and 1990s. As a result, dinar-denominated savings in banks and government securities (such as the "Loan for the Reconstruction of Serbia") lost value, while foreign currency savings held by citizens in banks were frozen from the early 1990s until 2002. These significant losses undermined the basic function of saving—transferring real income value from the present to the future—and increased public scepticism about the benefits of saving. The restoration of trust in savings began after 2000, as macroeconomic stability gradually improved and a solid banking system was established.

The establishment of macroeconomic stability in Serbia is illustrated by the decline in inflation—from about 50% annually in the late 1990s to around 10% annually between 2002 and 2013, and further down to an average of about 2% annually from 2014 to 2020, which is in line with the long-term average of developed countries. As a result of global market disruptions and expansive domestic fiscal and monetary policies during the COVID-19 pandemic, inflation reached double-digit levels in 2022 and 2023, but fell to 4.3% in 2024. Based on the above, it can be concluded that Serbia has made significant progress in reducing and stabilizing inflation since 2000. Maintaining low and stable inflation in the coming years is a necessary condition for Serbia's economic progress, including an increased willingness of households to save. From a savings perspective, keeping inflation low and stable is important in all countries, and especially in Serbia, which has had a long history of high inflation.

Given that a dual-currency system has existed in Serbia for decades, the stability of the dinar exchange rate is an important indicator of overall macroeconomic

stability. Since 2000, the stability of the dinar exchange rate has improved significantly compared to previous decades, which were marked by the existence of official and black market exchange rates and periodic major devaluations of the official dinar rate. Between 2001 and 2016, the dinar steadily depreciated, but at a relatively low rate—on average, it lost 4.6% of its value against the euro annually over 16 years. After 2016, Serbia adopted a de facto fixed exchange rate policy for the dinar, which is favourable for macroeconomic stability and savings. However, such a policy can have negative effects on foreign trade, potentially accelerating price convergence with European levels and adversely impacting economic growth.

Figure 9. Inflation and exchange rates in Serbia



Source: Ministry of Finance of Serbia

In general, a fixed exchange rate policy yields positive long-term results if it is aligned with other policies, especially income and fiscal policies. However, in several years, this alignment did not occur in Serbia, as the fixed exchange rate policy was accompanied by faster growth in real wages than in labour productivity, while fiscal policy remained expansionary. Due to a large inflow of foreign direct investment, this policy has not caused major macroeconomic issues so far, but it could do so in the future. For the quasi-fixed exchange rate policy to have positive macroeconomic effects, it is necessary to maintain a relatively low fiscal deficit in the coming years and ensure that real wages grow in line with productivity. Additionally, changes in the structure of the economy are required, by increasing the share of high-productivity jobs, to eliminate the gap between real wages and productivity.

One of the fundamental conditions for saving to be economically rational is that real interest rates must not be negative, as only in that case can the real value of income be preserved over time through saving. Unlike the decades-long practice in socialist Yugoslavia, interest rates on dinar savings in Serbia have been mostly positive in real terms since the mid-1990s. The only exception was the post-COVID inflation period, during which, similarly to Europe, real interest rates in Serbia were negative. A policy of maintaining positive real interest rates on savings is one of the key conditions for increasing the household saving rate to levels seen in developed countries.

Figure 10. Annual real interest rates on term dinar deposits of households, in %



Source: National Bank of Serbia

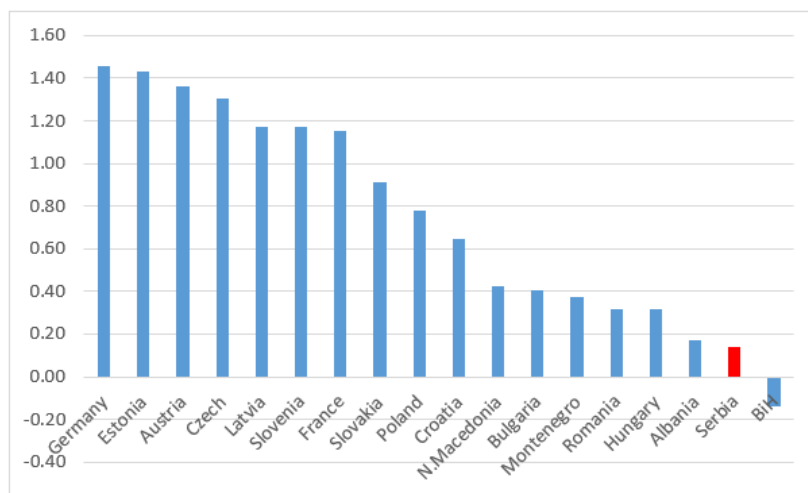
4. FORMAL INSTITUTIONS AND CULTURE

Insurance as a form of long-term saving is based on trust between policyholders and insurance companies. This trust is grounded in an appropriate institutional framework that defines the conditions under which insurance companies operate and includes oversight by state regulatory bodies, ensuring their long-term solvency. In Serbia, the regulation and supervision of insurance companies are largely aligned with international standards, which suggests that the legal framework directly governing insurance is not currently a barrier to its development and modernisation. However, rapid changes in technology, demographic characteristics, and the environment are transforming the context in which insurance companies operate, necessitating an adaptation of regulations to these evolving conditions.

The broader institutional framework affecting the functioning of the insurance market includes the rules for investing collected insurance premiums, the existence of incentives for insurance, and the efficiency of contract enforcement. The institutional framework regulating Serbia's capital market is inadequate, resulting in an underdeveloped market for both equity and debt securities²⁰⁸. This limits investment opportunities for insurance companies and ultimately reduces the return on insurance premiums. The development of the insurance market, particularly in countries without a strong tradition in this field, can be encouraged by introducing tax and other incentives. In Serbia, tax incentives exist for private pension insurance but not for private life and health insurance. From the perspective of efficiency and equity, there is justification for extending tax incentives to life and health insurance, while limiting the total amount of insurance premiums exempt from personal income tax.

The long-standing stagnation of the private pension insurance market, despite existing tax incentives, indicates that such incentives alone are not sufficient. Therefore, it is reasonable to consider introducing non-tax incentives, such as automatic enrollment of employees into a private pension insurance plan, with the right to opt out.

Figure 11. Regulatory quality by country in 2023



Source: World Bank – Worldwide Governance Indicators (WGI)

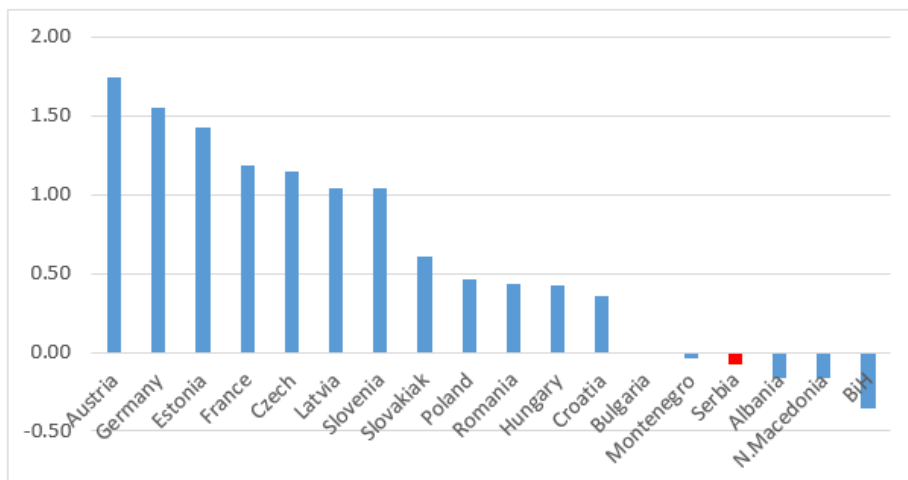
For all economic sectors—especially those that rely on long-term contracts and trust—it is essential to have a high-quality regulatory framework that is

²⁰⁸ Šoškić (2025), op. cit.

consistently enforced. Although Serbia has made progress in regulatory quality since 2000, it still ranks among the weakest in Europe in this regard (see Figure 11). This is partly due to delays in establishing a market economy and corresponding legislation during the 1990s, compared to other former socialist countries. Another reason is that since 2010, Serbia has significantly slowed the improvement of its regulatory quality, and since 2014, the quality has fluctuated from year to year without a clear upward trend. As a result, in 2023, Serbia ranked second-to-last among European countries in terms of regulatory quality.

In addition to the generally low quality of regulation, another issue is the inconsistent application of laws over a long period in Serbia. As a result, the country, along with other Western Balkan nations, ranks among the lowest in Europe in terms of the rule of law (see Figure 12). Since 2015, the state of the rule of law in Serbia, as well as its relative position compared to other countries, has worsened. The development of insurance in Serbia would benefit from improvements in regulatory quality, strengthening the rule of law, and enhancing the competence of public administration. However, it appears that there is currently no political will in Serbia to systematically work on improving the quality of regulations and their consistent application. Since laws are adopted through political processes and these processes affect their enforcement, without a shift in political attitudes towards the importance of legal quality and consistent application, no improvement in this area can be expected.

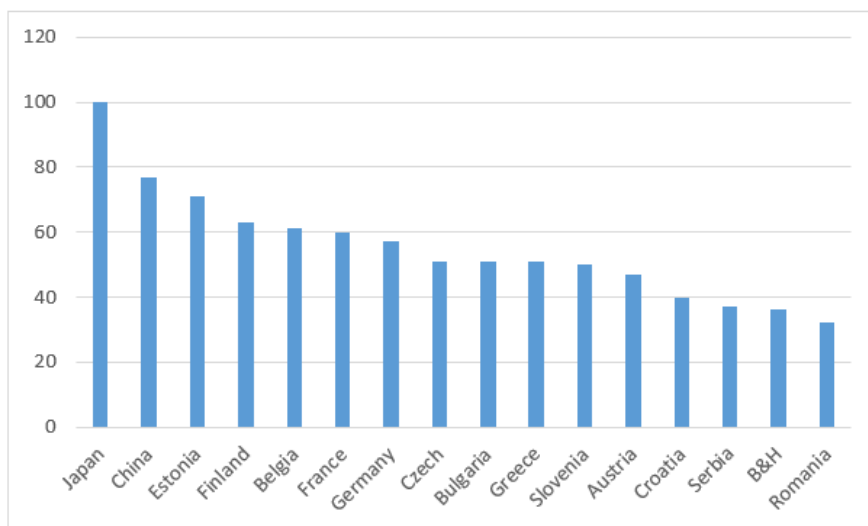
Figure 12. Rule of law by country in 2023



Source: World Bank – Worldwide Governance Indicators (WGI)

People's willingness to participate in insurance partially depends on their value system, primarily on whether they consider the long-term consequences when making decisions. The tendency to consider the long-term consequences of their decisions increases individuals' readiness for long-term saving, and thus for utilising insurance services. According to research by The Culture Factor Group, Serbia is among the countries whose citizens are relatively less oriented towards long-term decision-making, which implies that they are not particularly inclined to long-term saving (see Figure 13). This orientation in Serbia is likely a consequence of the turbulent historical circumstances since the early 20th century. Throughout the 20th century, Serbia spent nearly a third of its time involved in wars or under sanctions imposed by key economic partners. Additionally, Serbia frequently went through harsh internal political conflicts, including coups and political assassinations. In the economic realm, significant uncertainty was created by the nationalization of private property after World War II, as well as hyperinflation and the devaluation of the dinar. During periods of great uncertainty, such as wars, sanctions, internal conflicts, and hyperinflation, people tend to focus on short-term survival, while the long-term consequences of their decisions take a back seat.

Figure 13. Long-term orientation by country



Source: *The Culture Factor Group*

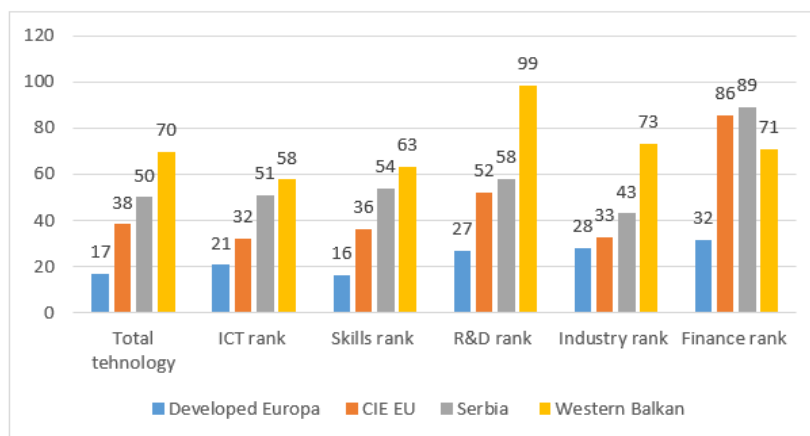
Extended periods of uncertainty have shaped value systems and behaviors adapted to such circumstances, which persist even when society is in a period of relative stability. From the perspective of insurance, this means that, in addition to previously mentioned factors (income growth, return growth, macroeconomic

stability, fiscal incentives, etc.), a long period free from wars, sanctions, and internal conflicts is necessary for its development. Mitigating the negative impact of historical legacies on the willingness to save can be achieved through systematic encouragement of saving. These incentives can be implemented through the education system, media, and public awareness campaigns. One important message that can be conveyed to people is that public pensions in the future will be relatively low, and it is necessary for individuals to save for their retirement in various ways.

5. TECHNOLOGICAL ADVANCEMENT AND INSURANCE MODERNISATION

The modernisation of insurance involves the application of modern digital technologies for data collection, processing, and prediction, such as Artificial Intelligence (AI) and Machine Learning, Big Data and Analytics, Blockchain, Data-Driven Decision-Making, etc. The application of these technologies aims to ensure better risk assessment, cost reduction, enhanced data security, more accurate premium determination, better service adaptation to consumer needs, and improved prediction of trends in the economy, society, and the natural environment.

Figure 14. Ranking countries for readiness for frontier technologies in 2022

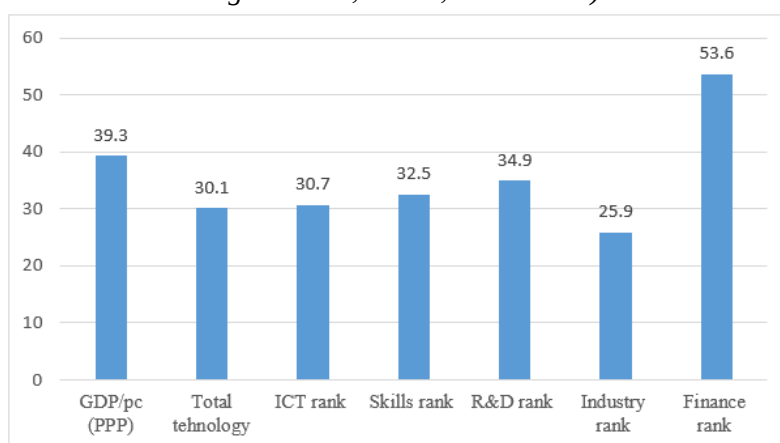


Source: UNCTAD (2023). *Technology and Innovation Report 2023: Opening Green Windows – Technological Opportunities for a Low-Carbon World*. Geneva: UN

Serbia's readiness for insurance modernisation, in addition to macroeconomic circumstances, depends on its willingness to adopt new technologies. According to the 2022 rankings, Serbia ranked 50th out of 166 countries in terms of readiness to adopt new technologies. It achieved the best position regarding its

ability to adopt new technologies in the industry, and the weakest in terms of adopting financial innovations. Its ability to adopt innovations in the IT sector and the skill level of workers were at the general average for the adoption of new technologies (see Figure 14). Regarding the readiness to adopt new technologies, Serbia is significantly behind developed European countries and slightly behind the EU member states of Central and Eastern Europe (CEE), while it is in a much better position compared to other Western Balkan countries. Serbia's readiness to adopt innovations in the financial sector is weaker than the Western Balkan average.

Figure 15. Percentile rank of Serbia in the world in 2022 (ranges from 0, highest rank, to 100, lowest rank)



Source: UNCTAD (2023), op. cit.

Serbia's readiness to adopt new technologies is at a higher level than its development level, measured by GDP per capita in purchasing power parity dollars. The exception is the financial services sector, where Serbia is ranked lower in terms of readiness to adopt advanced technologies compared to its development level (Figure 15). According to the development level, measured by GDP per capita in purchasing power parity USD in 2022, Serbia was in the 39th percentile globally, while in terms of overall readiness to adopt technological innovations, it was in the 31st percentile. Given that Serbia's ability to adopt innovations in most areas exceeds its development level, it can be concluded that its ability to adopt new technologies is not a barrier to its economic progress, at least in the next few years. However, due to the lag in adopting new technologies compared to developed countries, and even compared to Central and Eastern European countries, achieving a high level of development requires improving the technological state in Serbia across all sectors. Serbia's greatest lag in terms of readiness to adopt innovations is in the financial sector, so it is essential to

create an adequate regulatory framework in this area to stimulate technological progress and overall development of the financial sector. The first step in this is a change in the government's stance towards the development of the financial sector, in the sense that it is important to develop all its segments, not just banks.

Given that the modernisation of insurance is technologically closely related to digitalisation, we will now analyse Serbia's position according to the global Digitalization Index constructed by Huawei. The Global Digitalization Index was created for 77 countries based on 42 indicators that cover four main areas: ubiquitous connectivity, digital foundation, green energy, and policy & ecosystem. The indicators within ubiquitous connectivity focus on telecommunications performance, such as the development of 5G and 5 G-A networks, the prevalence of fibre access, and the Internet of Things. The digital foundation includes indicators like investment in digital technologies, the capacity of data centres, future-proof computing power and storage, cloud computing, and computing networks. The green energy area includes indicators related to the share of renewable, ecologically clean energy sources in the country, which is becoming an increasingly important criterion, as new IT technologies consume large amounts of electrical energy. The policy & ecosystem indicators and areas refer to the quality of regulation, spectrum distribution policies, IT investment, conditions for the formation and development of IT startups, and more.

According to Huawei's methodology, countries are divided into three groups based on their level of digital technology development. The first group consists of 22 countries with the best digitalisation performance, which contribute significantly to the development and progress of technology in this area (front-runners). The second group includes 30 countries that predominantly adopt created techno-logies (adopters), and the third group consists of 25 countries that are in the early stages of digitalisation (starters). According to the Huawei list, Serbia is in the lower part of the adopters group, ranked 45th among all 77 countries. Although this position looks significantly worse than on the UN list, it would likely be similar if the Huawei list contained the same number of countries as the UN list.

A more detailed analysis reveals that Serbia, compared to the average of the 77 countries, lags the most in the areas of ubiquitous connectivity and digital foundation, somewhat less in the area of policy & ecosystem, and the least in the area of green energy. In the field of ubiquitous connectivity, Serbia was rated the worst regarding the spread of 5G networks, Internet Protocol Version 6 (IPv6), and the prevalence of high-speed internet with a flow rate of over 10 G. Serbia has been lagging for several years in the implementation of the 5G network, and the reasons are likely the financial unpreparedness of the state-owned

telecommunications operator to enter this area and compete with private operators. In the area of digital foundation, the weakest performance is in data creation, cloud investment, and advanced storage investment, while Serbia is highly rated in terms of e-government. In the area of green energy, Serbia received the lowest scores on most criteria (renewable electricity, investment, green travel ratio, charging convenience, renewable electricity utilization rate). However, Serbia's rank in this area is relatively good, as most other countries perform poorly in terms of green energy production. In the policy & ecosystem area, Serbia has the best absolute scores, but its rank is relatively low because the situation in other countries is rated relatively well. Looking at individual indicators in the policy & ecosystem area, Serbia performed well in several areas such as internet participation, smartphone penetration, ICT laws & regulations, and online video streaming, but performed poorly in areas like the number of startups, ICT patents, ICT investment, and e-commerce transactions. It is likely surprising that Serbia received a relatively low score for ICT investment (2 out of 10 possible points).

Table 2. Global Digitalization Index for 2024 – Comparison of Serbia with selected countries

Technology Enablers	Average	Serbia	Slovenia	Germany
Ubiquitous Connectivity	45.0	38.4	50.4	53.6
Digital Foundation	44.0	38.4	39.6	66.0
Green Energy	32.0	31.2	31.2	50.4
Policy & Ecosystem	58	53.5	60.0	74.8

Note: GDI is within the range of (0.100), where a higher index value implies better performance in the field of digital technology.

Source: Huawei (2025). *Global Digitalization Index*, publication and website

Serbia's position regarding the overall state of technology and its ability to adopt it is somewhat more favourable compared to its rank in terms of development level. This means that the ability to adopt advanced technologies, at least in the next few years, will not pose a barrier to economic growth or the modernisation of insurance. However, even in the field of technology, Serbia significantly lags behind Central and Eastern European countries in certain areas. Serbia is particularly poorly ranked in terms of its ability to adopt innovations in the financial sector, which is reflected in the underdevelopment of non-bank financial institutions, including life and private pension insurance. In the IT sector, the situation in Serbia is mixed – in some areas, such as e-government, Serbia is well-ranked, but it significantly lags behind in the implementation of 5G networks and high-speed internet.

Chapter 9.

THE INFLUENCE OF MONETARY POLICY ON THE FINANCIAL SECTOR

Central banks represent the backbone of the economy of a country. They are responsible for maintaining liquidity in the market and ensuring the smooth functioning of the financial system. They regulate and monitor the amount of money in circulation, in order to ensure sufficient liquidity for the normal development of economic activities, without inflation or deflation. With its tools, such as open market operations, key interest rates, regulation of required reserves, central banks ensure an adequate amount of money in circulation, affect the availability of capital, price stability, and the functioning of the financial sector, they prevent financial crises and enable the smooth operating of the economy.

The money market, as the main channel for the implementation of monetary policy, enables quick and efficient distribution of liquidity among the participants in the financial system. Central banks affect important parameters of this market, such as overnight and other interest rates, closely related to the key monetary policy rates. In addition, central banks regulate and supervise financial institutions that participate in this market, which contributes to its stability and smooth functioning. Central Banks also manage national payment systems, which efficient functioning is a prerequisite for the normal and smooth conducting of financial transactions and circulation of liquidity in the economy. Management of foreign exchange reserves and implementation of foreign exchange policy enables maintaining the stability of the national currency and the balance of payments.

1. CHALLENGES THAT SHAPED MONETARY POLICY OVER NEARLY TWO DECADES

In the last two decades, monetary policy has faced major challenges. A long period of stable growth was disrupted by the US sub-prime mortgage crisis, which quickly spread to other economies due to interconnectedness of financial institutions and markets. The crisis stemmed from excess liquidity and low interest rates, that fuelled credit expansion and financial innovations. Instead of raising consumer prices, this liquidity inflated asset values, particularly in real estate. Mortgage securitization allowed lenders to offload risk by bundling loans into mortgage-backed securities (MBS), which investors receive income from borrowers' payments. This process extended to other credits, such as car and

student loans, creating asset-backed securities (ABS). As financial markets evolved, different securities were pooled into collateralized debt obligations (CDOs), that were divided into risk tranches. Since these were very complex products, it was very hard to value them, which led to widespread mispricing. The abundance of liquidity reduced risk premiums, encouraging excessive leverage and speculation. Rising financial product values artificially boosted reported profits under fair-value accounting rules²⁰⁹.

Financial innovations, primarily the process of securitization, have introduced major changes in interbank, covered bonds and sovereign debt markets, in the process of financial intermediation, bank financing and monetary policy transmission. The focus in financing has shifted to the short-term segment of the financial market. This has increased banks' exposure to financial conditions on the interbank market and reduced the impact of changes in the key interest rates. Financial innovations have contributed to the emergence and development of a large number of non-deposit financial institutions, called shadow banking. These are financial institutions that perform credit, maturity and liquidity transformation, without access to central bank liquidity or government credit guarantees. They perform the process of credit intermediation by transforming risky long-term assets into short-term liabilities, issuing securities such as commercial papers and other asset-backed securities, collateralized bonds and repo arrangements²¹⁰. At the global level, the non-banking financial sector participated with around 47% in the total assets of the financial sector²¹¹, and in the euro zone, banks have a little over 1/3 of the assets of the financial sector (58% in 1999)²¹². Under the pressure of competition from these financial institutions, banks have increasingly become involved in the derivative securities market. Their credit activity has increasingly been financed through the securitization process. An increasing proportion of interbank loans used these derivatives as collateral. So, the banks' funding costs and thus their interest rates depend on the conditions in the structured securities market, the covered bond market and collateralized interbank loans. Banks have also become dependent on the conditions in the sovereign debt market - the value and availability of these securities, as these bonds have been treated by regulators as a safe investment.

²⁰⁹ Popović, S., & Lukić, V. (2009). Central Bank Policy and Financial Crisis. *Scientific conference*, Niš: University of Niš, Faculty of Economics, pp. 533-540

²¹⁰ Popović, S., Janković, I., & Lukić, V. (2017). Interconnectedness between shadow and traditional banking system in Europe, *Bankarstvo*, 46(3), doi: 10.5937/bankarstvo.1703014P

²¹¹ <https://www.fsb.org/wp-content/uploads/P181223.pdf>

²¹² <https://www.ecb.europa.eu/press/fie/html/ecb.fie202406~c4ca413e65.en.html#footnote.29>

The financial fragility materialized in 2008, with a surge of interruption in debt repayment and foreclosures and the burst of the housing market bubble, leading to a sharp decline in real estate prices and triggering massive losses for institutions holding sub-prime assets. Major firms collapsed, including Bear Stearns, Lehman Brothers, and AIG, leading to a credit crunch that paralyzed lending and spread economic pessimism globally²¹³.

The outbreak of the crisis caused a great aversion of investors to risk, that become overvalued. The bankruptcy of Lehman Brothers caused a panic in the repo market, not a classic banking panic when deponents massively withdraw their deposits from banks. The perception of counterparty risk increased dramatically and banks were no longer willing to lend in the interbank market. The ability of banks and other financial intermediaries to lend in this market depends on the size, structure and quality of the collateral portfolio. MBS and other structured securities became undesirable as collateral, thus the market focus was on government bonds. While in the US repo market, risk aversion meant that investors fled to US government bonds, which yields had fallen significantly, in Europe investors began to differentiate between the bonds of individual countries, which led to a large increase in spreads. A sharp segmentation of the market according to the structure of collateral emerged. Financial institutions that had a large share of MBS in their collateral portfolios lost access to this market²¹⁴.

Households, seeing their financial wealth decline, cut spending and increased savings. Previously, rising asset prices had encouraged them to consume more rather than save, but the crisis forced a reversal of this behavior. Businesses, facing economic uncertainty, reduced investments and inventory, deepening the downturn.

The financial collapse of 2007-2009 prompted unprecedented central bank interventions. Emergency monetary policies included massive liquidity injections, quantitative easing (QE), and bailouts to stabilize financial

²¹³ Lukić, V., & Popović, S. (2010). The Assessment of Banking Sector Performance in Current Economic Crisis: Success or Failure. In: *The International Conference - The Challenges to Economic Theory and Policy in the Aftermath of the Global Economic Crisis, Proceedings*, Skopje: University Ss. Cyril and Methodius, Faculty of Economics, pp. 203-219.

²¹⁴ Popović, S., & Živković, A. (2016). Funkcija zajmodavca u krajnjoj instanci Evropske centralne banke kao odgovor na finansijsku krizu. *21st International Scientific Conference SM2016 - Strategijski menadžment i sistemi podrške odlučivanju u stratezijskom menadžmentu, Proceedings*, Subotica: University of Novi Sad, Faculty of Economics in Subotica, pp. 681-693.

institutions. Governments coordinated responses to restore confidence and prevent systemic collapse.

The new function of central banks: Market maker of last resort

The classic Lender of the last resort function rests on the assumption that the functioning of credit markets depends on confidence in the solvency of financial institutions. When that trust disappears, central banks intervene as a lenders of last resort, providing credit support to banks that, after exhausting all other options, no longer have sources of funding for their daily operations. However, their bankruptcy would significantly affect the financial system and economy of the country. In this way central banks prevent the spread of banking panics. During the period of the Great financial crisis (GFC), central banks had to expand their function of the lender of last resort and become Market makers of the last resort. This type of operation goes beyond the standard provision of liquidity, but still rests on central banks' monopoly in the supply of liquidity.

During serious crises, assets that are normally accepted as collateral can become undesirable. In conditions of intensive collateralized financing, the conditions of liquidity and the functioning of the market, are determined by the availability of collateral, not the spread on the money market or trust in banks. The functioning of collateralized credit markets depends on trust in the collateral, not in the institutions, which makes the system unstable because the value of the collateral is an endogenous variable. It depends on the market demand for the given collateral, and less on the fundamental characteristics (risk and return) of the given security. The value of the collateral is very procyclical and subject to major changes during the financial crisis, its reduction intensifies the consequences of the crisis. After the outbreak of the GFC, the value of collateral in US dropped significantly, because everyone wanted to sell the same securities. This created large losses and funding problems for both financial institutions and the real sector and deepened the crisis.

A credit crunch or liquidity crisis manifests itself through the poor functioning of financial markets. The spread of uncertainty among participants means that there will be little or no trading of certain securities (like ABS, MBS or CDO), while they become undesirable. There is no credible market maker that would regularly publish purchase and sale prices. The solution to the problem is for the central bank to become the market maker of the last resort. The central bank performs this function through direct purchases and sales of a wide range of private sector securities, or by accepting these securities as collateral in its operations. In this way, it ensures that these securities remain liquid and acceptable in the market. It actually transforms the collateral, replaces the private sector's securities, which value the market doubts, with its liabilities on a large scale. As market makers,

central banks influence price transparency, the size of transaction costs (the spread), and the volume of money market trading. They accept illiquid private sector securities and determine their value. They strive to minimize short-term interest rate fluctuations and increase the predictability of their movements in the future. This in turn encourages the transmission of monetary policy through financial institutions and markets to the real economy.

The rise in the quantity of money in circulation and the decrease in interest rates

Quantitative easing (QE) led to substantial rise of central banks' balance sheets and reductions in key interest rates. Before the crisis, FED held approximately \$700–800 billion in Treasury notes, and in 2014 \$2.5 trillion. Holdings of MBS reached \$1.8 trillion, and the total assets grew to \$4.5 tn by October 2014 (from \$1 tn in September 2008). Bank reserves grew from less than \$50 billion to \$2.2 billion in 2017²¹⁵. In euro area, central bank assets grew from around €1.2 tn to around €3.1 tn in 2012²¹⁶. Bank of England monetary base grew very fast, from close to £69 billion in January 2009 to £208 billion in July the same year²¹⁷, while its balance sheet increased from around £100 billion to around £270 billion in this period²¹⁸ (Figure 1).

At the same time, key policy rates were significantly reduced. ECB rate on main refinancing operations was reduced from 5.25% during the third quarter of 2008 to 0.25% in 2016, while the rate on deposit facility was in negative zone (-0.4%) in 2016²¹⁹. The fed funds rate was lowered from 5.25% in the mid of 2007 to 0.07% in July 2011²²⁰. The main rate of Bank of England was reduced from 5.75% in July 2007 to 0.25% in August 2016²²¹.

²¹⁵https://www.everycrsreport.com/files/20170627_IN10727_9a3f8ee35d5ede0fa4e50dce7d269e0521fbad3c.html

²¹⁶<https://fred.stlouisfed.org/series/ECBASSETSW>

²¹⁷<https://ideas.repec.org/a/fip/fedlrv/y2010inovp481-506nv.92no.6.html>

²¹⁸<http://piketty.pse.ens.fr/files/capitalisback/CountryData/UK/VariousOfficialSeries/BalanceSheetBoE/Fisher09.pdf>

²¹⁹https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html

²²⁰<https://fred.stlouisfed.org/series/FEDFUNDS>

²²¹<https://www.bankofengland.co.uk/boeapps/database/Bank-Rate.asp>

The influence of the pandemic on monetary policy

Since the outburst of financial crisis, financial sector has been flooded with the abundance of liquidity in the environment of very low, even negative interest rates. That has caused concerns among central banks related to possible inflation growth, and thus plans for the exit strategy²²². However when they were about to start with balance shrinking and increasing of their key rates, new severe shock occurred: Covid-19 pandemic. In March 2020, the pandemic emerged, prompting governments worldwide to implement restrictive measures to slow the spread of the disease.

These measures disrupted global supply and demand, leading to sharp declines in private and investment consumption and significant deteriorations in macroeconomic performances. Many countries experienced their deepest economic contractions since the World War II, during the second quarter of 2020²²³. To support citizens and struggling businesses and to combat the ensuing economic crisis and potential recession, governments and central banks introduced new quantitative easing measures²²⁴, which led to substantial increase in the money supply in the circulation²²⁵.

Central banks balance sheets grew even stronger (Figure 1). The peak was at the end of 2021 and the first half of 2022. ECB assets increased to more than €8.8 trillion²²⁶, assets of FED reached approximately \$9 trillion, and total assets of BoE grew to more than £1.1 trillion²²⁷.

²²²http://www.federalreserve.gov/monetarypolicy/files/FOMC_PolicyNormalization.pdf

²²³ Popović, S., Lukić, V., & Živković, A. (2021). Central Banks Support to Financial Markets, Banking and Insurance in Response to Covid-19 Crisis. In: *Contemporary challenges and sustainability of the insurance industry*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp.79-96.

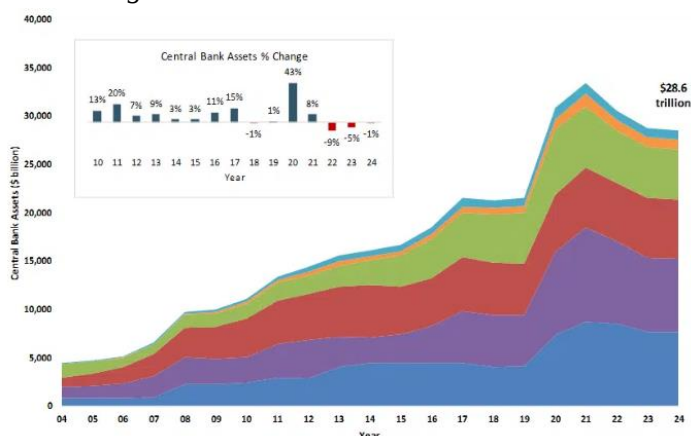
²²⁴ Janković, I., Popović, S., & Lukić, V. (2021). EU Monetary and Fiscal Policy Responses to the Covid-19 Crisis. *Ekonomika preduzeća*, 69(5-6), pp. 333-344, https://www.ses.org.rs/uploads/ep_5-6_2021_211202_171222_127.pdf

²²⁵ Popović, S., Lukić, V., & Živković, A. (2023). High Inflation and Rising Interest Rates as the Key Characteristics of the Economic Environment. In: *Challenges and Insurance Market's Responses to the Economic Crisis*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 59-74.

²²⁶ https://ycharts.com/indicators/european_central_bank_total_assets

²²⁷ <https://en.macromicro.me/charts/54371/boe-total-assets>

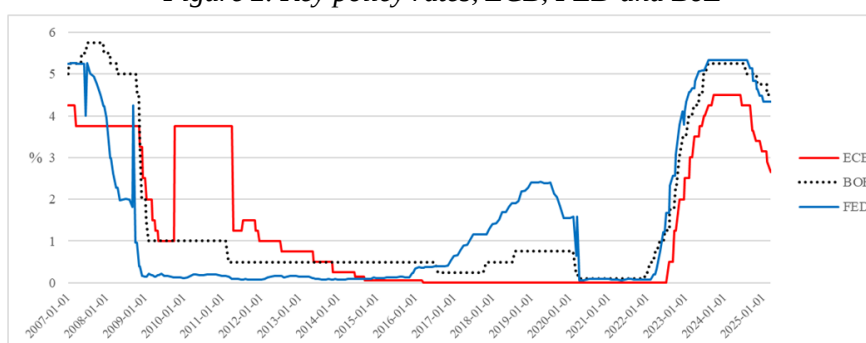
Figure 1. Global central bank balance sheets



Source: <https://www.riskbridgeadvisors.com/2024/01/05/january-5-2024-a-run-on-at-central-banks/>

At the same time, key policy rates reached record lows (Figure 2). FED immediately reduced fed funds rate from 1.58% at the beginning of pandemic to 0.65% and kept reducing it to the lowest level of 0.05%. This rate remained below 1% until June 2022. ECB kept its rate on main refinancing operations at the level of 0%, as well as rates on deposit facility of -0.5% and lending facility of 0.25%. Main refinancing rate was 0% from March 2016 until August 2022 (and from December 2011 it was 1% and lower). BoE also cut its key policy rate from 0.75% at the beginning of pandemic to 0.1%. In a very long period, key rate was 1% or lower, from February 2009 until June 2022.

Figure 2. Key policy rates, ECB, FED and BoE

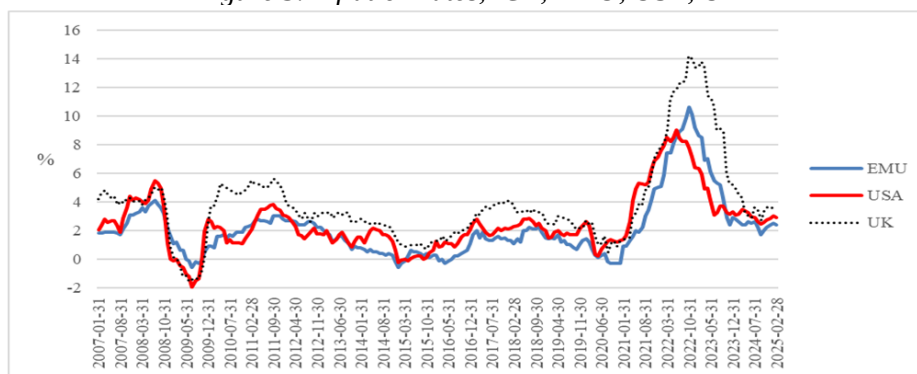


Source: Author, based on data from: Key ECB interest rates, https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html; Official Bank Rate history, <https://www.bankofengland.co.uk/boeapps/database/Bank-Rate.asp>; Federal Funds Effective Rate, <https://fred.stlouisfed.org/series/FEDFUNDS>

Inflation volatility and central bank measures

Due to a massive increase in the money supply combined with production constraints and disruptions in distribution chains, inflation began rising at the end of 2021. The situation worsened in February 2022 with the outbreak of war in Ukraine, a major grain producer, and the sanctions imposed by the US and Europe to Russia, which is both a key market for Western goods and a crucial supplier of essential resources like oil and gas. These sanctions triggered an unprecedented surge in food and energy prices, leading to double-digit inflation levels in 2022. Additionally, Europe's shift toward a green economy introduced uncertainties, production challenges, and rising costs, further exacerbating economic instability.

Figure 3. Inflation rates, ICP, EMU, USA, UK



Source: Author, based on data from: Euro area, <https://data.ecb.europa.eu/data/data-sets/ICP/ICP.M.U2.N.000000.4.ANR>; Consumer price inflation, Office for National Statistics, UK, <https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/czbh/mm23>; Consumer Price Index for All Urban Consumers, HICP - Overall index, FRED, <https://fred.stlouisfed.org/graph/?q=8dGq>

Inflation rates were quite volatile in the observed period. Until GFC, EMU had relatively stable inflation rates, in line with the ECB target. When the crisis emerged inflation rose, but the economic downturn that followed, caused significant decline in inflation, which reached the bottom of -0.6% in July 2009. ECB implemented measures like the Covered bond purchase programme (CBPP) in 2009²²⁸ and the Securities markets programme (SMP) in 2010²²⁹ to stabilize the financial system. Despite these efforts, the EMU faced a sovereign debt crisis, particularly in countries like Greece, Portugal, and Italy, leading to deflationary pressures. In the long period (2013- mid 2021), Eurozone struggled with

²²⁸ https://www.ecb.europa.eu/press/pr/date/2009/html/pr090604_1.en.html

²²⁹ <https://www.ecb.europa.eu/press/pr/date/2010/html/pr100630.en.html>

persistent low inflation, that prompted the ECB to adopt more aggressive monetary policies²³⁰. In 2015, the ECB launched an Expanded asset purchase programme (quantitative easing, QE) to combat deflation and stimulate the economy. Pandemic in 2020 caused economic contraction and influenced ECB to introduce the Pandemic emergency purchase programme (PEPP) to support the economy. These measures, along with supply chain disruptions and increased energy prices, contributed to a significant rise in inflation, that started in the second half of 2021. In October 2022, HICP surged to a peak of 10.6%, making one of the highest inflation rates in the EMU's history. In response to soaring inflation, the ECB shifted towards monetary tightening, raising benchmark interest rates multiple times, to curb inflationary pressures. In the 2023 and the first half of 2024 inflation was above ECB's target, but the second half of this year brought stabilization. In March 2025, the ECB reduced its benchmark interest rate by a quarter percentage point to 2.5%, followed by additional reductions. ECB announced cautious approach to future rate cuts, reflecting a balance between stimulating growth and maintaining price stability.

In US, inflation also was around 2%, before GFC. The soaring of energy prices and the reduction of fed funds rate caused inflation spike to 5.5% in July 2008, however it quickly plummeted to negative territory by 2009, indicating deflation. The Fed implemented the first round of Quantitative Easing in November 2008, purchasing MBS to inject liquidity into the financial system²³¹. Inflation remained subdued until 2011, fluctuating between 1–2%. The Fed launched QE2 in November 2010, purchasing Treasury securities, and QE3 in September 2012, with open-ended purchases of MBS. The fed funds rate stayed at very low level, close to 0% until December 2015. In 2011 and the first quarter of 2012, inflation was between 2-3%, then again dropped below 2%, reaching negative levels in 2015. At the end of 2014, and throughout 2015 and 2016, inflation was lower than 2%, often close to 0%. From 2017 until pandemic, it stabilized around 2%. The Fed incrementally increased the fed funds rate, reaching 2.25–2.50% by December 2018. It also commenced balance sheet normalization by reducing its holdings of Treasury and MBS. In March 2020, Fed slashed the fed funds rate back to 0.00–0.25% and initiated QE4, purchasing approximately \$700 billion in assets to support the economy during the pandemic. Inflation surged, reaching levels not seen in decades. Since March 2020 inflation was in a constant rise, peaking 9% in June 2022. Fed responded by aggressively raising the fed funds rate, implementing multiple hikes to curb inflationary pressures. In 2023 inflation rates were also high, but 2024 and the beginning of 2025 brought moderation. In

²³⁰ Popović, S., Janković, I., & Lukić, V. (2023). Heterogeneity of inflation processes in European monetary union. *Ekonomika preduzeća*, 70(7-8), pp. 373-382.

²³¹ <https://www.federalreserve.gov/newsevents/pressreleases/monetary20081125b.htm>

September 2024, Fed lowered its benchmark rate for the first time since 2020, by 50 basis points, reflecting confidence in economic stabilization. Fed emphasized a cautious "wait and see" approach to further rate adjustments, focusing on interpreting long-term economic signals amid ongoing policy fluctuations.

Inflation in UK was higher during 2007 and 2008. In mid-2007 UK faced depreciation of sterling (of 25%), which boosted inflation. It reached 5.0% in September 2008, due to rising commodity prices, but fell sharply afterward as the recession took hold. As the global financial crisis loomed, the BoE maintained the Bank Rate at 5.75% until December 2007, when it began a series of cuts to support the economy, to a historic low of 0.5% by March 2009. In March 2009, it launched the Asset Purchase Facility, initiating quantitative easing to stimulate the economy. In June 2009 inflation reached bottom of -1.6%, with 12 months of inflation significantly below 2% (which is BoE's target). During the period of 2010-end to 2014, inflation again was higher, reaching maximum of 5.6% in September 2011²³², but in 2015 and the first half of 2016 inflation fell significantly below 2%. Following period, until the outburst of pandemic was characterized by higher inflation, followed by 12 months of significantly low level of inflation, due to reduced demand. Period from 2016-2019 was marked by Brexit referendum and economic uncertainty, but also depreciation of pounds and rise in import prices. Then already at the beginning of the second quarter of 2021 inflation started to rise above BoE target, reaching maximum of 14.2% in October 2022. It still did not come back to the level of target. In response, the BoE commenced tightening monetary policy by raising the bank rate from 0.1% in late 2021 to 4% by 2023, it also began reducing its QE holdings.

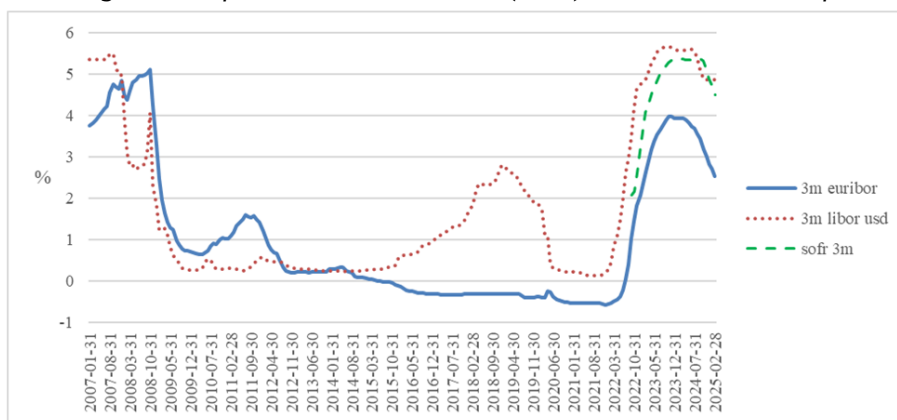
Reference interest rates

Volatile inflation, changes in market liquidity, and changes in key policy rates, caused volatility in reference interest rates. In 2007, both 3m Euribor and 3m Libor were relatively high, Euribor even rose towards the end of 2008, reaching 5.11% in October (Figure 4). ECB maintained higher key interest rates to combat rising inflation during this period. Increased banks' demand for liquidity also contributed to higher interbank lending rates. Since financial crisis led to reduced economic activity and inflationary pressures, ECB had to cut its interest rates and introduce measures to enhance liquidity, which caused drop of interbank lending rates. 3m Euribor reached the bottom of 0.65% in March 2010. After that, it started to rise, peaking to 1.6% in July 2011, before declining to 1.19% in December 2012. Concerns over sovereign debt in several Eurozone countries led to increased interbank lending rates. The ECB's interventions, including long-term refinancing operations (LTROs), provided liquidity and helped stabilize

²³² <https://obr.uk/box/why-has-inflation-been-higher-in-the-uk-than-the-euro-area/>

rates. Period from the beginning of 2013 until the surge of inflation in 2022, was characterized by Euribor close to zero and even falling into negative zone²³³ (in 86 consecutive months, 3m Euribor was negative, with the lowest value of -0.58% in December 2021). ECB maintained low key interest rates and implemented QE programs to stimulate economic growth and counter deflationary pressures in this period, resulting in sustained low interbank lending rates. Pandemic prompted the ECB to introduce additional monetary easing measures, including the PEPP, to support the economy, keeping interbank lending rates at even lower levels. Surge in inflation and increase in ECB interest rates to combat inflation, lead to corresponding increases in interbank lending rates. The growth trend started in July 2022 and lasted until November 2023, when 3m Euribor reached maximum of 3.97%. After that it slowly calmed down and to the value of slightly above 2.5% in February 2025. The ECB has reduced interest rates amid concerns over weak economic growth and potential trade tensions. In March 2025, ECB cut rates by a quarter percentage point to stimulate growth, lowering borrowing costs for consumers and businesses (Figure 2)²³⁴.

Figure 4. Reference rates- 3m Libor (USD), 3m Euribor, 3m Sofr



Source: <https://data.ecb.europa.eu/data/datasets/FM/FM.M.GB.USD.RT.MM.USD3MSR.HSTA>; <https://data.ecb.europa.eu/data/datasets/FM/FM.M.U2.EUR.RT.M.M.EURIBOR3MD.HSTA>; https://gee.bccr.fi.cr/indicadoreseconomicos/cuadro_s/frmvercatcuadro.aspx?idioma=2&codcuadro=%206883

Before GFC, 3m USD Libor was higher than 3m Euribor, reaching maximum of almost 5.5%, due to Fed maintaining higher fed funds rate to curb inflationary pressures. Besides, robust economic growth led to increased demand for credit,

²³³ Lukić, V., & Popović, S. (2025). Interest rate pass-through to deposit interest rates in a dual currency monetary system: Case of Serbia. *Ekonomski horizonti*, forthcoming.

²³⁴ <https://apnews.com/article/european-central-bank-ecb-interest-rates-eurozone-d0df8908a463ff8b000ff858691a0025>

keeping interbank lending rates elevated. In response to early signs of economic slowdown and the subprime mortgage crisis, Fed began cutting interest rates in September 2007. Since Libor is closely tied to the Fed's rate, lower policy rates reduced borrowing costs for banks, leading to a decline in Libor to 2.69% in May 2008. Following the collapse of Lehman Brothers in September 2008, the 3-month USD Libor spiked, reaching approximately 4.06% in October 2008. This happened due to: severe liquidity crisis (banks stopped lending to each other, fearing counterparty risk and insolvency), credit market freeze (despite Fed rate cuts, interbank lending rates surged as banks became reluctant to extend short-term credit) and heightened systemic risk (the financial crisis escalated, leading to Libor rise). In 2009, Libor reached values closer to 0, and remained below 1% until 2017, when it was still at the level below 2%. In 2018 Libor was higher than 2% (but lower than 3%, in response to steady economic growth and rising inflation), at the end of 2019 it fell again below 2%. With the emergence of the pandemic, it fell close to 0, with minimum of 0.12% in September 2021). The Fed's swift actions to cut the fed funds rate to near-zero levels and implement extensive QE measures injected substantial liquidity into the financial system, driving Libor rates down. In 2022, Libor started to rise, reaching maximum of 5.67% in September 2023. After that it stabilized at the high level of around 4.85%²³⁵. FED monetary policy tightening, for the sake of combating high inflation, caused increase in short-term rates, including Sofr.

2. CONSEQUENCES OF LOW INTEREST RATES IN THE FINANCIAL SECTOR

Low interest rates, close to 0% or even negative, were meant to fight very low inflation expectations and increase inflation rates. Reduction of borrowing costs for businesses and consumers, was supposed to motivate savers to spend and businesses to invest. However, although central bank unconventional measures (negative interest rates, market maker of last resort) supported economic recovery and boosted credit growth, they also compressed banking profits, fueled asset bubbles, and increased financial vulnerabilities.

The influence on banks' NIM was twofold. Banks faced surge in loan demand, while low interest rates facilitated mortgage, auto and corporate lending. In USA,

²³⁵ Libor was phased out at the end of 2021, and market participants were encouraged to use risk-free interest rates like Secured Overnight Financing Rate (SOFR: 1,3,6 and 12 months). In June 2017, the US Federal Reserve Bank's alternative reference rates committee selected Sofr as the preferred alternative to Libor. The New York Federal Reserve began publishing the rate in April 2018. SOFR took the place of Libor in June 2023.

consumer loans rose from \$319 billion in February 2010, to \$873 billion in December 2019²³⁶. Commercial and industrial loans increased from \$1.18 trillion (July 2010) to \$3.07 tn (May 2020)²³⁷. Bank real estate loans grew from \$3.49 tn to close to \$4.7 tn (April 2020)²³⁸. In euro area, bank loans to households rose from around €5.1 trillion at the beginning of GFC to €6.65 tn at the end of 2021²³⁹. Also, the non-performing loans (NPL) were reduced, in USA from 5% in 2009, to 0.86% in 2019²⁴⁰, as refinancing became easier. In euro area NPLs reached peak in 2013 of around 8%²⁴¹, and fell to 1.79% in Q3 2022²⁴². On the other side NIM fell. NIM in US was 3.81% in 2010 and fell to 3.25% in 2015²⁴³, in following 3 years it slightly rose, but fell to 2.54% in 2021 and 2.95% in 2022²⁴⁴, indicating reduced profitability. The number of FDIC insured institutions declined from more than 8,500 before GFC, to 4,487 in 2024²⁴⁵ reflecting a significant consolidation within the U.S. banking industry during that period. In euro area, bank profitability was even lower. NIM in 2008 was slightly below 2.1% and fell to 1.5% in 2010, it later rose to 2.1% in 2014²⁴⁶, but immediately after, it fell. In EU the lowest ratio was in July 2021: 1.18%²⁴⁷. The number of credit institutions has declined substantially, from 7,520 in December 2009 to 3,142 in December 2024²⁴⁸. Negative policy rates significantly lowered short-term rates and lending rates, but the transmission to retail deposit rates was limited. Cash and the possibility for deposit withdrawals disabled European banks to charge negative rates on deposit held by households and businesses. So,

²³⁶ <https://fred.stlouisfed.org/series/CCLACBM027NBOG>

²³⁷ <https://fred.stlouisfed.org/series/BUSLOANSNSA>

²³⁸ <https://fred.stlouisfed.org/tags/series?t=loans%3Busa&et=&pageID=1>

²³⁹ <https://data.ecb.europa.eu/main-figures/banks-balance-sheet/loans?tab=Households&indicator=Adjusted+loans%2C+total+-+stocks>

²⁴⁰ <https://fred.stlouisfed.org/series/DDSI02USA156NWDB>

²⁴¹ https://www.bde.es/f/webbde/GAP/Secciones/Publicaciones/InformesBoletinesRevisas/RevistaEstabilidadFinanciera/18/NOVIEMBRE/Non_performing_loans_ingles.pdf

²⁴² <https://www.statista.com/statistics/1122984/non-performing-bank-loans-in-europe/>

²⁴³ <https://fred.stlouisfed.org/series/DDEI01USA156NWDB>

²⁴⁴ <https://www.fdic.gov/quarterly-banking-profile/fdic-quarterly-v18-n4-3rd-quarter-2024>

²⁴⁵ <https://www.fdic.gov/quarterly-banking-profile>

²⁴⁶ <https://fred.stlouisfed.org/series/DDEI01EZA156NWDB>

²⁴⁷ <https://data.ecb.europa.eu/data/datasets/SUP/SUP.Q.B01.W0.Z.I2120.T.SII.Z.Z.Z.PCT.C>

²⁴⁸ <https://data.ecb.europa.eu/search-results?searchTerm=number%20of%20credit%20institutions>

banks that were financed dominantly by deposits, faced higher shrink of NIM than banks that relied more on wholesale markets²⁴⁹.

To offset reduced NIMs, banks turned to fee-based services and trading activities. In US, the ratio between total non-interest and interest income in 2007 was 32%, it grew to 53.7% until 2013 (in the period 2009-2021 it varied around 50%)²⁵⁰. Higher deposit banks in Europe increased lending to households and businesses, especially to riskier and smaller firms, and invested in higher-yielded assets-private debt securities²⁵¹. Since the financial crisis, fees and commissions have become an increasingly important source of income for European banks. The EU weighted average of net fee and commission income to total net operating income has increased from 2014-2024, peaking at 32.9% in March 2020. Throughout 2022 and 2023 it fell, in September 2024 it was almost 28%²⁵². Trade revenues of commercial banks and saving associations in US have been volatile, but had strong increasing trend since mid-2012 (\$2 billion), reaching maximum of \$17.6 billion in Q1, 2023²⁵³. This shift exposed banks to higher market risks and volatility, especially when it comes to activities like trading and investment banking.

The EU banking sector has consistently shown lower profitability compared to the US banking sector: it did not return to pre-GFC profitability levels. In 2021, the return on equity (RoE) in the Eurozone was 6.7%, significantly lower than 11% recorded by US banks. By Q2 2022, this gap had narrowed slightly, with Eurozone RoE at 7.6% and US RoE at 9.9%. Before the crisis, both regions had similar RoE, exceeding 10% comfortably. Additionally, Eurozone banks have consistently faced a higher cost of equity compared to their US counterparts. In 2022, the cost of equity was around 8.4% in the Eurozone, compared to 6.5% in the U.S., further limiting European banks' profitability and competitiveness.

Weaker performance has been reflected in bank valuations, with price-to-book (P/B) ratios of European banks below 1 for a decade, and market capitalization

²⁴⁹ <https://blogs.worldbank.org/en/allaboutfinance/upside-down-banks-deposits-and-negative-rates>

²⁵⁰ <https://fred.stlouisfed.org/series/DDEI01EZA156NWDB>

²⁵¹ <https://www.imf.org/en/Publications/WP/Issues/2019/02/28/Negative-Monetary-Policy-Rates-and-Portfolio-Rebalancing-Evidence-from-Credit-Register-Data-46638>

²⁵² <https://www.statista.com/statistics/1124912/net-fee-and-commission-income-to-total-net-operating-income-for-banks-in-europe/>

²⁵³ <https://www OCC.gov/publications-and-resources/publications/quarterly-report-on-bank-trading-and-derivatives-activities/index-quarterly-report-on-bank-trading-and-derivatives-activities.html>

shrinking compared to US banks. That suggested investors' concerns about shareholder value, and caused higher costs of capital from issuing additional equity. Bank market valuations have been influenced by several factors, including profitability trends, management and operational efficiency, regulatory capital levels and overall macroeconomic conditions²⁵⁴. Before GFC, long-term weighted average of the P/B ratios of euro area and US banks was around 2 and 2.4, respectively. Until March 2009 P/B ratio fell sharply to 0.5, data for both country groups followed similar path, but the US banking sector saw a much stronger recovery afterwards. Since 2010, and more clearly from 2011 onward, average P/B ratios in the US have remained higher. European ratio again fell to 0.5 in 2011 and even lower in following year. Although the ratios converged somewhat in 2014-15, the gap began widening again from 2016 onward. From 2013-2020 US banks ratio varied in the range from 1-1.5, but European banks ratio remained lower than 1 (slightly above 1 in 2014 and 2015)²⁵⁵ In 2001 ratios were 0.6 for European banks and 1.5 for US banks. In 2007 market cap for European banks was €2.7 trillion, while for US banks it was €1.6 tn. In 2012, market cap for US banks remained the same, while for European banks it fell sharply to €1.5 tn. In 2021 market cap of European banks fell even more to €1.4 tn, but for US banks it increased to €2.6 tn²⁵⁶.

GFC had a more severe and prolonged impact on European banks than on US banks. US policymakers responded swiftly, providing large-scale equity injections and FED interventions, allowing banks to recover faster. In contrast, when the EU faced the sovereign debt crisis, its response was hindered by fragmentation, fiscal constraints, and competition policies, forcing banks to manage prolonged uncertainty. While US banks focused on recovery and growth, European banks had to build large capital buffers to manage risks, including NPLs. This cautious approach, combined with slower Eurozone economic growth (1.0% annually vs. 1.6% in the US), led to weaker bank performance, lower profits, and lower valuations. Additionally, lending opportunities declined, with domestic credit to the private sector falling from 102% to 92% of GDP in the EU (2010-2020), while it rose from 182% to 217% in the US. The uneven economic

²⁵⁴ https://www.ecb.europa.eu/press/financial-stability-publications/fsr/focus/2019/pdf/ecb~a18359e8d9.fsrbox201905_05.pdf

²⁵⁵ https://www.bde.es/f/webbde/Secciones/Publicaciones/InformesBoletinesRevistas/InformesEstabilidadFinancera/19/ficheros/fsr_2019_2_Box2_1.pdf

²⁵⁶ https://www.ebf.eu/wp-content/uploads/2023/02/The-EU-banking-regulatory-framework-and-its-impact-on-banks-and-the-economy_30Jan-1.pdf

recovery within Europe further penalized banks with exposure to weaker economies²⁵⁷.

The persistent low profitability of European banks threatens financial stability, as profitability serves as the first defense against financial shocks. Unprofitable banks struggle to build reserves, making it harder and more expensive to raise capital in times of crisis. Low market valuations reflect investors' skepticism about European banks' ability to generate future earnings, regardless of external or internal factors. As a result, banks face constraints on lending expansion, business model upgrades, and mergers or acquisitions. Additionally, prolonged weak profitability may push banks toward excessive risk-taking in pursuit of higher returns, potentially increasing financial instability.

When interest rates across all debt maturities are near-zero or negative, it poses significant challenges for institutions that rely on bonds for income, like banks, insurance companies (IC) and pension funds (PF). Life insurers, which invest premiums in bonds to meet future claims, face lower returns, which impacted their ability to offer attractive policy benefits. Also defined-benefit pension plans struggle to meet future obligations as bond yields decline, potentially leading to funding shortfalls. Low interest rates cause the present value of liabilities to rise more than that of assets for ICPFs, which affects their solvency. Besides, the desire of claimholders to terminate life insurance contracts early, can become a source of liquidity vulnerability for insurance companies, if a period of low interest rates ends with a sudden quick rise. Prolonged period of very low and decreasing interest rates might mean that insurers face guaranteed rates exceeding yields available on highly rated sovereign bonds. Thus, they are forced to invest in high-yielding high-risk instruments²⁵⁸, like private equity or real estate, to achieve higher returns, which may introduce liquidity and valuation risks.

Banks can benefit from the revaluation of longer-term assets (consistent with a positive duration gap between assets and liabilities) in the period of decreasing interest rates. ICPFs typically have negative duration gaps, while their liabilities tend to have longer duration than their assets. In the case of decreasing discount rates, the value of liabilities will rise more than the value of assets, reducing their solvency²⁵⁹. There is however the difference between non-life and life insurance companies, while non-life insurers contracts are usually with short maturity (one

²⁵⁷ https://www.ebf.eu/wp-content/uploads/2023/02/The-EU-banking-regulatory-framework-and-its-impact-on-banks-and-the-economy_30Jan-1.pdf

²⁵⁸ https://www.oecd.org/en/publications/oecd-journal-financial-market-trends/volume-2011/issue-1_fmt-v2011-1-en.html

²⁵⁹ <https://www.bis.org/publ/cgfs61.pdf>

year), and life insurers contracts are with long maturity, that could be even several decades. Life insurers also often have explicit return guarantees like guaranteed interest-rate returns, guaranteed minimum income streams and similar that could be difficult to fulfil in an environment of prolonged low interest rates on government bonds and stagnating or deteriorating capital-market valuations.

In both US and Europe, investors seeking higher returns often shift from traditional fixed-income securities to riskier assets, leading to asset price inflation and potential bubbles. FED low-interest rate policy and global saving glut caused housing prices boom before GFC, but also one that ended in 2022, in US. It lead to increase in wealth, consumer spending and a deterioration in current account deficits, exacerbating global imbalances²⁶⁰. In some areas housing prices rose more than 3 times from 2012 to 2022. Median sale price of houses sold for the US doubled in that period²⁶¹. Investors also seek higher returns in the stock market, driving up equity prices. Nasdaq price-to book ratio, in September 2010 was 0.61 and remained below 1 until very end of 2014, after that it started increasing reaching maximum of 5.23 at very end of 2021²⁶². In EU house prices rose close to 55% from 2013 to 2022²⁶³. Share prices in euro area rose 2.2 times from 2012 until the end of 2021²⁶⁴. Long-term government bond yields with 10-years maturity for Euro area reached maximum of 4.7% in April 2011 and fell to low of -0.1% at the January 2021, and from the second half of 2019 to the beginning of 2022, they varied close to 0%²⁶⁵.

3. HIGH INFLATION, RISING RATES AND QUANTITATIVE TIGHTENING

Hudge liquidity injections, low and negative key rates, post-pandemic economic recovery, supply chain disruptions, war in Ukraine and sanctions to Russia, led to explosion of commodity prices and sharp increase in inflation in 2022. After a long period of very low, even negative rates, inflation in many countries turned to double digit levels.

²⁶⁰ <https://www.sciencedirect.com/science/article/pii/S0261560623001201>

²⁶¹ <https://fred.stlouisfed.org/series/MSPUS>

²⁶² <https://www.macrotrends.net/stocks/charts/NDAQ/nasdaq/price-book>

²⁶³ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Housing_price_statistics_-_house_price_index

²⁶⁴ <https://fred.stlouisfed.org/series/SPASTT01EZM661N>

²⁶⁵ <https://fred.stlouisfed.org/series/IRLTLT01EZM156N>

Inflation has consequences for the financial service industry. Bank income and expenses related to borrowing and lending are indirectly affected by inflation, as they depend on policy rates, which central banks adjust in response to inflation. On the other hand, non-traditional banking revenues, service fees, salaries and rent are directly impacted by price changes, as they fluctuate with overall inflationary pressures.

When it comes to interest business, maturity composition and mismatch between income and expense, shape bank exposure to inflation (largely indirectly through policy rates). Interest-earning assets and interest-bearing liabilities that are not fixed in nominal terms, are typically linked either directly to policy rates or to market rates that move in tandem with policy rates. Income and expenses from long-term assets or liabilities with fixed contractual payments that do not adjust frequently, will remain insensitive to market fluctuations. Opposite, financial assets with short maturities or those that reprice regularly tend to be highly responsive to changes in market conditions. In the non-interest business, the degree of price and wage rigidity for services provided and costs incurred can create direct exposure to inflation. Some banks rely heavily on fee-based income streams, where pricing may adjust in response to inflationary pressures. Inflation influences also the asset quality. On one side, it may make debt financing easier for borrowers, assuming that policy rates remain the same or increase to a smaller extent. On the other side, inflation triggers monetary policy response and rise in key rates, so borrowers may face larger debt servicing costs for debts indexed to some reference interest rate²⁶⁶.

Central banks responded to rising inflation by increasing their key policy rates and withdrawing liquidity. ECB increased rate on main refinancing operations 10 times, from 0% until July 2022 to 4.5% in September 2023 and they remained high until June 2024. Fed increased key rate 11 times, from March 2022 until July 2023, when it reached maximum of 5.25-5.5% (Figure 2). As a consequence, leading interest rate indicators rose sharply (Figure 4). Euribor 3m rose to 3.97% in November 2023, while Libor 3m rose to 5.66% in September 2023.

Rapid growth of market rates had consequences in the financial sector. Initially high interest rates increased banks' NIM, as lending rates increased faster than deposit rates. In European union, NIM started to rise sharp from Q4 2022, reaching 1.69% in March 2024²⁶⁷, while bank's net profits rose by around 32%

²⁶⁶ <https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2025/02/10/Inflation-and-Bank-Profits-Monetary-Policy-Trade-offs-557542>

²⁶⁷ <https://www.eba.europa.eu/publications-and-media/press-releases/eueea-banks-profitability-holding-well-despite-declining-net-interest-margin>

since the previous year, driven by large increase in net interest income. RoE grew from 8.1% in December 2022 to 10.4% in December 2023. On the other side, net fee and commission income and, to a lesser extent, net trading income made negative contributions to RoE (34 bps and 12 bps respectively)²⁶⁸. In US net interest margin grew to 3.3% in 2023 and then slightly fell to 3.22% at the end of 2024²⁶⁹. RoE reached 11.81% at the end of 2022, but fell slightly to 11.37% in 2024. Since competition for deposits intensified, banks had to offer higher interest rates to attract and retain customers, compressing NIMs²⁷⁰.

The extensive policy support implemented during the pandemic led to a significant increase in savings, which in turn boosted bank deposits. A substantial portion of these deposits was invested in long-duration securities, exposing banks to considerable interest rate risk. As interest rates continued to rise, banks faced higher financing costs and a decline in the market value of their securities holdings, leading to a sharp rise in unrealized losses on held-to-maturity and available-for-sale portfolios. FDIC insured corporations had substantial losses on their securities portfolio, in 2023 the loss was \$11.5 billion, while in 2024 it was \$6.2 billion²⁷¹. Unrealized losses on banks' investment securities peaked in the Q3 2023 at \$750 billion, but decreased to \$513 billion in the Q2 2024²⁷², after interest rates reduction started²⁷³. Unfortunately, some banks- even large institutions were not prepared for the high-interest rate environment after a long period of low rates. In March 2023, turmoil in the US banking sector sent shockwaves through the global financial system. The collapse of Silicon Valley Bank (SVB), the 16th largest US bank, was quickly followed by the failures of Signature Bank (SB) and First Republic Bank. These were the first-, the second- and the third-largest US bank failures since Washington Mutual in 2008, in US history. The failure of SV exposed deeper structural vulnerabilities in the business models of certain US banks- banks with large amounts of uninsured deposits, significant unrealized losses, and high exposure to commercial real estate.

The situation was exacerbated by a self-fulfilling deterioration in market confidence, which triggered widespread deposit outflows, especially among

²⁶⁸ <https://www.eba.europa.eu/publications-and-media/publications/profitability>

²⁶⁹ <https://www.fdic.gov/quarterly-banking-profile/fdic-quarterly-2025-volume-19-number-1>

²⁷⁰ <https://www.ft.com/content/dfb7732a-213b-4755-a017-e0f0d5f4b9f7>

²⁷¹ <https://www.fdic.gov/quarterly-banking-profile/fdic-quarterly-2025-volume-19-number-1>

²⁷² <https://www.fau.edu/newsdesk/articles/banks-securities-risk-losses.php>

²⁷³ <https://www.fau.edu/newsdesk/articles/banks-securities-risk-losses.php>

similarly sized or smaller banks. Additionally, deponents shifted toward higher-yield alternatives, such as money market funds, accelerating deposit outflows. While higher interest rates typically enhance bank profitability, the events of March 2023 highlighted how underestimated duration risk has been in the monetary tightening cycle. Technological advances, such as mobile banking and the rapid spread of information via digital communication, amplified the speed and scale of the deposit run, making it unlike any previous crisis in terms of velocity. The March 2023 episode highlighted how digitalization has increased the vulnerability of banks to sudden liquidity pressures, especially when investors sentiment turns negative. The US banking stress increased market uncertainty, global stock markets faced sharp decline, bank indices fell quickly and volatility rose. FED had to intervene again to stem systemic risks and broader contagion. It introduced the Bank term funding program, providing funds to banks at par, with no margin applied to the eligible collateral. Also, FDIC fully covered uninsured deposits at SVB and SBNY by invoking the “systemic risk exception.” This response underscored that, due to the interconnected nature of the financial system, even banks that are not classified as globally systemically important can still pose significant threats to financial stability²⁷⁴. Europe faced similar shock with Credit Suisse failure in the same period, which triggered global contagion effects. It caused abnormal returns for other globally systemically important banks across Europe, North America and Asia, while investors perceived heightened risks in the broader banking sector.

4. CONTEMPORARY CHALLENGES TO MONETARY POLICY

Monetary policy faces several significant challenges, including higher inflation, low growth rates (especially in European leading economy), trade war, financial dominance, fiscal imbalances, ongoing war in Ukraine and climate change.

Inflation rates in many countries have declined in 2024 and 2025, however, the war is still not won. Central banks have been gradually lowering their high key rates. The future path of the policy rates depends on a continuing decline of inflation towards targets. Key question for central banks is how to ensure disinflation and avoid damaging the economy. The goal is soft landing, with inflation back to the level of target, without inducing a recession or larger increase in unemployment. In US, inflation has been volatile in the previous couple of months, it reached the lowest level of 2.4% in September 2024, but then moved to opposite direction, reaching 3% in January 2024, and then dropping to 2.8% in February 2025 (Figure 3). Wall Street analysts expect that the introduction of

²⁷⁴ <https://www.imf.org/-/media/Files/Publications/gfs-notes/2024/English/GFSNEA2024001.ashx>

tariffs on key US trading partners and the immigration repression will likely lead to higher prices. They expect inflation of 2.5% for 2025 (rise from previous forecast of 2.3%). Manufacturers and service firms expected inflation over 2025 is 3.5-4%²⁷⁵. Core inflation in US (food and energy are excluded) was 3.1%²⁷⁶ in February and expectations for 2025 goes to 3% (up from 2.5% in earlier forecast). Due to persistent inflation, Fed might stop decreasing interest rates to cut borrowing costs for consumers and business. Since December 2024 Fed has been keeping its key borrowing rate between 4.25-4.5%, market doesn't expect its decrease soon, but Fed officials said that 0.5% reduction might happen in 2025, depending on inflation and situation in economy and labour market. Fed officials expect the economy to grow by 1.7% this year, down from a previous forecast of 2.1%. In 2026, two rate cuts are expected, followed by one more in 2027, bringing the fed funds rate to its long-term level of around 3%²⁷⁷. Fed also announced intentions to further reduce liquidity, by cutting its bond holdings. The unemployment rate was 4.1% in February and has been fluctuating around that level from May 2024. In the previous 2 years, it was lower, ranging between 3.2% and 3.9%²⁷⁸.

Inflation in Eurozone, in February 2025 has been 2.4%, and core inflation 2.6%²⁷⁹. ECB staff macroeconomic projection from March 2025, forecast inflation of 2.3% in 2025²⁸⁰. Investors, however doubt in further decrease of inflation in Europe (only 7% of European investors expect lower inflation in Eurozone in the next year²⁸¹). GDP growth for 2025 is forecasted at 0.9% in 2025, 1.2% in 2026 and 1.3% in 2027. The weaker economic outlook results from lower export projections and investment expectations due to a greater impact of uncertainty, and belief that competitiveness challenges will persist longer than previously expected. Further deterioration of outlook is possible, as these projections include only bilateral tariffs imposed by the US to Chinese imports. Additionally, there is potential for an increase in defense spending. Since June 2024, ECB has cumulatively reduced its key rates by 185 basis points through March 2025. However the timing and scale of future rate cuts remain uncertain,

²⁷⁵ <https://www.cbsnews.com/news/inflation-trump-tariffs-economists-forecast-2025/>

²⁷⁶ <https://www.bls.gov/news.release/pdf/cpi.pdf>

²⁷⁷ <https://www.cnn.com/2025/03/19/fed-rate-decision-march-2025.html>

²⁷⁸ <https://www.bls.gov/charts/employment-situation/civilian-unemployment-rate.htm>

²⁷⁹ <https://www.euronews.com/business/2025/03/19/euro-falls-as-eurozone-inflation-sees-downward-revisions-in-february>

²⁸⁰ [https://www.europarl.europa.eu/RegData/etudes/IDAN/2025/764374/ECTI_IDA\(2025\)764374_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/IDAN/2025/764374/ECTI_IDA(2025)764374_EN.pdf)

²⁸¹ <https://www.euronews.com/business/2025/03/19/euro-falls-as-eurozone-inflation-sees-downward-revisions-in-february>

due to higher uncertainty about global macroeconomic environment. ECB staff expects a 25-bps cut in April and additional cut in June, bringing the deposit facility rate down to 1.75%, indicating a more rapid easing cycle than previously anticipated²⁸².

A significant threat to the world economy comes from US tariffs on China (20%), Europe (25%), Canada (10-25%) and Mexico (25%), as well as retaliatory measures²⁸³. The US imposed several rounds of tariffs on Chinese import. In 2018 tariffs ranging from 10% to 25% were imposed on sectors like technology, machinery and consumer electronics. In 2024 additional tariffs were introduced on electric vehicles, batteries, solar panels and certain critical minerals, with rates set between 25% and 100% (effective from September 27, 2024). New tariffs were introduced in February 2025, with rates of 10% on all Chinese imports, which was increased to 20% in March²⁸⁴. In retaliation China implemented tariffs of 10 and 15% to US goods.

The tariff rate on non-energy products from Canada is 25%, while it is 10% on energy and potash²⁸⁵. In response, Canada imposed a 25% surtax on goods from the US²⁸⁶. Trump even announced a 50% tariff on Canadian aluminum and steel in retaliation for Canada's 25% surge on electricity exports to some US states. However, these tariffs were later suspended.

On March, US imposed tariffs of up to 25% on imports of steel, aluminum, and certain products containing steel and aluminum from the EU and other trading partners. (In June 2018, 10% tariffs were implemented on European steel and aluminum exports, then in January 2020 additional tariffs of EU exports of certain derivative steel and aluminum products)²⁸⁷. European Union responded by plans to impose counter-tariffs on some US goods, in April.

²⁸² [https://www.europarl.europa.eu/RegData/etudes/IDAN/2025/764374/ECTI_IDA\(2025\)764374_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/IDAN/2025/764374/ECTI_IDA(2025)764374_EN.pdf)

²⁸³ <https://taxfoundation.org/research/all/federal/trump-tariffs-trade-war/>

²⁸⁴ https://www.whitehouse.gov/fact-sheets/2025/02/fact-sheet-president-donald-j-trump-imposes-tariffs-on-imports-from-canada-mexico-and-china/?utm_source=chatgpt.com

²⁸⁵ <https://www.whitehouse.gov/fact-sheets/2025/03/fact-sheet-president-donald-j-trump-adjusts-tariffs-on-canada-and-mexico-to-minimize-disruption-to-the-automotive-industry/>

²⁸⁶ <https://www.cbsa-asfc.gc.ca/publications/cn-ad/cn25-10-eng.html>

²⁸⁷ https://ec.europa.eu/commission/presscorner/detail/en/qanda_25_750

New tariffs could reduce US import by 15%, but might generate around \$100 billion per year of extra federal tax revenue. On the other side, they will bring significant costs on the broader economy: disruption in supply chains, raising costs for businesses, elimination of hundreds of thousands of jobs and increasing consumer prices²⁸⁸. According to estimations, US tariffs will decrease US GDP for 0.4 percentage points (pp.) and loose hours worked by 309,000 full-time equivalent job (without accounting for retaliation measures)²⁸⁹. US makes 15% of China's total export, so China is less dependent on the US than before (and export and import make 37% of China's GDP). It has increased trade with EU, Mexico and Vietnam²⁹⁰. If tariffs to China remain on 20%, China's GDP might fall by about 0.6 pp. If Trump increases tariffs to 60% (as announced in his electoral campaign), the loss in GDP growth might rise to 2.5 pp.²⁹¹ Canada and Mexico will be hit harder, US makes 78% of Canadian export, and 80% of Mexican export. Mexican GDP might fall by 3pp.²⁹², Canadian GDP might decline 2-4%²⁹³. European GDP growth might be -0.4%, in the first year, due to tariffs. European exports to US are expected to drop by 15-17% in the first year, with even higher declines in German exports, potentially reaching up to 20%. In Germany, the manufacturing sector will likely be the hardest hit, with the automotive industry expected to see a 4% decline in production²⁹⁴. Retaliation measures will probably impact US fuel exporters, automakers and other advanced manufacturers, including pharmaceutical producers, the most.

Germany, the largest economy and economic engine of Europe, is grappling with structural challenges, as economic growth has stagnated in recent years. Key factors contributing to this slowdown include: labor and skilled worker shortages, excessive bureaucracy, high energy costs and insufficient investment. Export-driven model and limited domestic investment made Germany unprepared for future challenges. Germany's industrial base is shrinking, leading German companies are shifting portions of their production overseas, driven by lower costs and reduced bureaucratic barriers. Industrial production has been in steady decline, with output in 2024 falling to 90% of its 2015 level. The country has

²⁸⁸<https://www.cfr.org/article/what-trumps-trade-war-would-mean-nine-charts>

²⁸⁹<https://taxfoundation.org/research/all/federal/trump-tariffs-trade-war/>

²⁹⁰<https://www.cfr.org/article/what-trumps-trade-war-would-mean-nine-charts>

²⁹¹<https://www.eiu.com/n/the-impact-of-us-tariffs-on-china-three-scenarios/>

²⁹²<https://www.fitchratings.com/research/sovereigns/threat-uncertainty-of-us-tariffs-both-pose-risks-to-mexico-10-02-2025>

²⁹³<https://ppforum.ca/policy-speaking/what-tariffs-could-mean-for-the-canadian-economy/>

²⁹⁴<https://www.ifw-kiel.de/publications/news/trumps-tariff-threats-on-eu-could-trigger-economic-turmoil/>

consistently underinvested in critical areas, while restrictive fiscal policies have further constrained economic expansion. As the workforce shrinks, industries grapple with rising costs and an increasing need for automation. Although the country's unemployment rate remains low at 5%, industrial layoffs and restructuring are anticipated. Rising energy costs, fueled by volatile gas markets, are weakening Germany's competitiveness. Public investments are insufficient, accounting for only 2.8% of GDP—below the EU average of 3.6% and significantly trailing Poland (5.1%) and Sweden (5.2%). Bureaucratic hurdles and a reluctance to embrace deficit spending continue to hinder large-scale projects that could boost innovation and sustainability. Chinese manufacturers of electric vehicles, supported by substantial state subsidies and vertically integrated supply chains, have achieved cost efficiencies and advances in technology that pose a significant threat to automotive sector. Volkswagen, BMW and Mercedes-Benz are struggling with high production costs, regulatory hurdles and slow domestic EV adoption and losing global market share²⁹⁵. Germany's GDP is forecasted to grow only by 0.3% by IMF and 0.2% by Bundesbank, while the Association of German industry expects the contraction of the economy by 0.1% in 2025 (third annual decline in row)²⁹⁶.

Another challenge to monetary policy is financial dominance. The size of financial sector, high levels of private debt and suppressed risk premiums can limit the effectiveness of monetary policy tools and pose risks to financial stability. High levels of private debt can make economies more sensitive to interest rate changes, as households and businesses with significant debt may struggle with increased borrowing costs. This sensitivity can restrict central banks' ability to adjust interest rates without causing financial distress. Household debt varies across European countries. In 2024, household debt in Denmark, the Netherlands, Sweden and Norway was approximately twice the average national income²⁹⁷. According to some estimations, private credit market in US is around 30 trillion USD²⁹⁸.

Escalating fiscal deficits and public debt, present significant challenges to monetary policy in both Europe and the US. Factors such as population aging and

²⁹⁵<https://www.atlanticcouncil.org/blogs/new-atlanticist/germanys-economy-has-gone-from-engine-to-anchor/>

²⁹⁶<https://www.cnbc.com/2025/01/29/germany-slashes-economic-growth-expectations-ahead-of-february-election.html>

²⁹⁷<https://www.statista.com/topics/13191/household-debt-and-loans-in-europe/#topicOverview>

²⁹⁸<https://www.mckinsey.com/industries/private-capital/our-insights/the-next-era-of-private-credit>

geopolitical tensions further exacerbate these imbalances, complicating the task of maintaining economic stability. General government gross debt in Eurozone was higher than 88% of GDP in Q3 2024²⁹⁹, in US it was 123% in 2024³⁰⁰. High levels of public debt and persistent fiscal deficits constrain central banks' ability to implement effective monetary policies. Elevated debt levels can lead to higher interest rates, increasing the cost of borrowing and potentially crowding out private investment. Additionally, central banks may face pressure to maintain low interest rates to reduce government debt servicing costs, potentially compromising their ability to combat inflation.

Climate change can pose challenges to economic stability, prompting central banks to integrate environmental considerations into their policy frameworks³⁰¹. The increasing frequency and severity of climate-related events have direct and indirect economic impacts, influencing fiscal policies, financial markets, and monetary stability. There is increased demand for energy, change in agricultural patterns, water scarcity, significant investments in infrastructure are needed. Between 1980 and 2023, weather- and climate-related extremes caused economic losses totaling approximately €738 billion within the European Union³⁰². In US climate-related disasters from 2019-2023 were \$603 billion³⁰³. Climate-related disasters can lead to significant financial losses, affecting both public and private sectors. Banks exposed to high-risk areas may face increased default rates, necessitating enhanced risk assessments and capital buffers. Shifts in asset values due to climate risks require central banks to reassess collateral frameworks and adjust monetary policy tools accordingly. Climate-induced economic shocks can influence inflation and employment metrics, influencing monetary policy transmission and complicating the central banks' role in achieving price stability.

In recent years, monetary policy has undergone an unprecedented shift. The world has experienced the most severe pandemic since the 1920s, the largest conflict in Europe since the 1940s, and the most significant energy crisis since the 1970s. These shocks have reshaped the economic landscape, complicating the

²⁹⁹ <https://ec.europa.eu/eurostat/web/products-euro-indicators/w/2-22012025-ap>

³⁰⁰ <https://fiscaldata.treasury.gov/americas-finance-guide/national-debt/>

³⁰¹ Lukić, V., Popović, S. (2022). The response of monetary policy on the climate change. *Novi economist*. Vol. 16, Issue 32, pp. 61-74.

³⁰² https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation?utm_source=chatgpt.com&activeTab=fa515f0c-9ab0-493c-b4cd-58a32dfa0a0a

³⁰³ https://www.climate.gov/news-features/blogs/beyond-data/2023-historic-year-us-billion-dollar-weather-and-climate-disasters?utm_source=chatgpt.com

management of monetary policy. This challenge was further intensified by the fact that the pandemic struck after a prolonged period of sluggish growth, low inflation, and historically low interest rates.

Shifts in central bank interest rates policy, have had profound effects on financial institutions. The prolonged period of ultra-low rates following the 2008 financial crisis compressed net interest margins for banks, reducing profitability and pushing them toward riskier investments. The rapid rate hikes since 2022, aimed at controlling inflation, led to higher funding costs and a decline in the market value of long-duration assets, exposing banks to significant interest rate risk. This was evident in the U.S. banking turmoil of March 2023, when some large banks collapsed due to substantial unrealized losses on bond holdings. Similarly, European banks faced higher refinancing costs and asset revaluations, contributing to financial sector volatility and tightening credit conditions.

Chapter 10.

DEVELOPMENT OF SERBIAN DEPOSIT GUARANTEE SCHEME

Introduced in 1989, in an effort to defuse a systemic banking crisis in former Yugoslavia, Serbian deposit guarantee scheme (DGS) has been reformed and consistently strengthened over time, in both regulatory and operational terms. Through consecutive legal successions following the collapse of Yugoslavia, responsibility for operating the DGS in Serbia was assumed by the Deposit Insurance Agency (DIA) in 2005. In 2008, the deposit insurance coverage limit and scope were significantly increased in response to the 2007-2008 Global Financial Crisis. Several years later, in 2015, the DGS's role in a bank resolution process was redefined within a broader reform of the Serbian bank resolution regime. Another major step towards full transposition of the EU acquis governing deposit insurance in Serbian legislation was taken in 2019, with modification of the regular premium assessment base, introduction of risk-based premium assessment as an option, and temporary higher deposit insurance coverage in case of bank mergers or acquisitions.

This chapter aims to describe the evolution of Serbian DGS over the span of 35 years, and demonstrate the stabilizing impact of explicit and limited deposit insurance on Serbian banking industry and public confidence. The evolution of Serbian DGS will be placed in international, regional, and national contexts to explain the intentions behind specific reforms and what they achieved. Also, in view of Serbia's anticipated accession to the EU, an overview of sequential transposition of European Directive 2014/49/EU on deposit guarantee schemes (EU DGSD) in Serbian legislation will be provided, including the regulatory amendments planned to take effect going forward, in conformance with the National Program for Adoption of the Acquis (NPAA).

1. ROLE AND CONCEPT OF DEPOSIT INSURANCE

Deposit insurance protects depositors from losses in case of a bank failure by providing them access to their funds in the shortest possible time. In times of crisis, it prevents runs on banks by removing depositors' incentive to withdraw cash in fear of bank insolvency. A robust deposit guarantee scheme preserves and

strengthens the financial stability, and promotes public confidence in the banking system, thus creating a more favorable environment for bank savings growth.³⁰⁴

A credible system clarifies the deposit insurer's obligations to depositors, limits arbitrary decision-making, and ensures a less costly and orderly resolution of failed banks. On the other hand, if designed inadequately, it may encourage parties to take more risks under the assumption that losses, at least partially, would be borne by others.³⁰⁵

Consequently, the design of a deposit guarantee scheme is approached carefully and in close cooperation among all safety-net players. All features of the DGS design must be chosen in light of economic realities of a given jurisdiction, and the declared public-policy objectives, including: governance, explicit or implicit coverage, membership, funding model, target fund, coverage limit, scope of coverage, speed and method of reimbursement, investment policy, etc. Characteristics of Serbian DGS will be discussed in more detail below.

2. ORIGINS OF DEPOSIT INSURANCE SCHEMES GLOBALLY

The concept of deposit insurance as a scheme that protects communities against occasional distresses in the banking industry and prevents losses to depositors first appeared in the USA in the late 1820s.³⁰⁶ Limited to specific states, these insurance plans generally failed to produce long-lasting results. On the US federal level, the insurance plan which covered limited balances and guaranteed their repayment to depositors in case of a bank failure was established in 1933, following the stock market crash in 1929, closure of about 9,000 banks nationwide, and month-long bank runs. Faced with such an unprecedented financial crisis, the newly inaugurated US President Franklin D. Roosevelt proclaimed a week-long suspension of all bank operations in the US territory. Assured by the measures taken by the federal administration and the promise that only stable and healthy banks would reopen after the Bank Holiday, within the first two weeks, bank customers redeposited more than half of the sum previously withdrawn from banks. This effectively ended the 1929-1933 US banking crisis.³⁰⁷

³⁰⁴ Krstić, B., & Radojičić, J. (2012). Osiguranje depozita kao *ex ante* i *ex post* antikrizni mehanizam u bankarstvu. *Ekonomске teme*, 50(4), p. 536.

³⁰⁵ International Association of Deposit Insurers (2014). *Core Principles for Effective Deposit Insurance Systems*. Basel: IADI, p. 11.

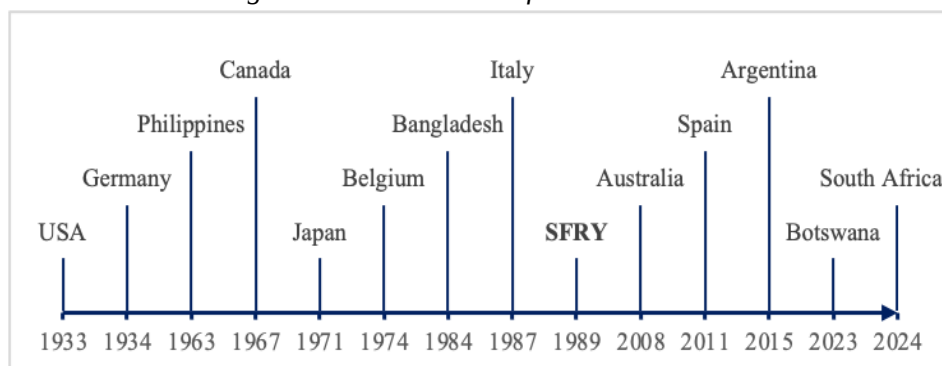
³⁰⁶ Federal Deposit Insurance Corporation (1984). *The First Fifty Years*, Washington, DC: FDIC, p. 3.

³⁰⁷ Silber, W. L. (2009). Why Did FDR's Bank Holiday Succeed? *FRBNY Economic Policy Review*, July 2009, pp. 19-20.

What convinced the public that the new system would in fact work was the Federal Reserve's commitment under the Emergency Banking Act of 1933 to provide unlimited financial support to reopened banks in case of liquidity issues. The same act created the Federal Deposit Insurance Corporation (FDIC). Globally, some forms of deposit insurance schemes already existed earlier,³⁰⁸ but the US scheme established in the wake of the Great Depression is considered the first institutional government-backed deposit guarantee system in the world.

The number of countries with an operational DGS grew steadily after the Second World War, spreading to Central and East Asia, Latin America and Europe. Development of DGSs globally was largely the result of cyclical financial and economic crises, which made national authorities recognize the necessity of devising systemic approaches to regulating the financial sector and preserving or restoring public confidence in the banking industry. In some cases, deposit guarantee schemes were designed as part of broader bank restructuring programs (e.g., Hungary, Japan, Jordan) or regulatory improvements to tackle bank insolvencies and enhance bank supervision.³⁰⁹ More recently, the 2008 Global Economic Crisis prompted the creation of more DGSs around the world and reform of the existing ones.

Figure 1. Establishment of DGSs worldwide



Note: The above overview is by no means exhaustive and serves only as an illustration of development of DGSs globally over the past 90 years.

Source: IADI Survey 2024

³⁰⁸ Since 1921 in Norway, and from 1924 in Finland and Czechoslovakia; however, all were relatively short-lived.

³⁰⁹ International Association of Deposit Insurers (2004). Questions on the Design of a Deposit Insurance System. Summary of Responses, *Research paper*, Basel: IADI, p. 5.

3. YUGOSLAV DEPOSIT GUARANTEE SCHEME BETWEEN 1989 AND 2005

In former Yugoslavia, DGS was established in 1989, by virtue of the Law on the Federal Agency for Deposit Insurance and Bank Rehabilitation and the Banking Law.

In late 1980s, Yugoslav banking system was going through a major crisis. A nationwide bank audit showed that over two thirds of all Yugoslav banks were effectively insolvent, having accumulated losses in excess of USD 10 billion.³¹⁰ At the close of 1987, losses of the banking sector were estimated at USD 12.6 billion.³¹¹ Situation in the banking sector was partly the result of problems faced by the national economy at large. In 1989, inflation was soaring, with consumer price indices growing by 2,600 per cent in a year.³¹² Companies were in habit of repaying their debts by taking out new loans from banks with suboptimal underwriting policies, which tended to gloss over their own risk exposure or creditworthiness of their corporate clients. To make matters worse, the same companies were co-founders of the lending banks and controlled their loan committees. In absence of adequate loan classification systems and operational controls, banks managed to conceal their accumulated and current losses for an extended period of time.³¹³

Macroeconomic indicators continued to worsen. During the 1980s, Yugoslav federal government took a variety of sweeping measures intended to restore the faltering national economy back to health, by attempting to secure support from international financial institutions to repay external debt and boost economic growth. Consequently, in 1989, Federal Government presented its Economic Reforms Programme with Implementation Measures, while the National Bank of Yugoslavia released its Yugoslav Banks Restructuring Programme in the following year. Both programmes involved comprehensive bank rehabilitation efforts, which could be systemic, bank-specific or both.

³¹⁰ Aristóbulo de Juan y Asociados, S.L. (1990). Bank Restructuring in Yugoslavia - A Summary Overview, *Consultative paper*, p. 1.

³¹¹ Federal Executive Council of the SFRY (1989). *Obrazloženje Predloga Zakona o obezbeđivanju sredstava za osnivanje i rad Agencije federacije za osiguranje depozita i sanaciju banaka*, Belgrade, II, p. 1.

³¹² Đukić, P. (2018). Ekonomska politika, sankcije i hiperinflacija: Pouke iz haosa, In: *Prilozi za privrednu istoriju Jugoslavije i Srbije. Hiperinflacija i posthiperinflacija*, Đukić, Đ., Živković, A. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, p. 75.

³¹³ Aristóbulo de Juan y Asociados (1990), op. cit., p. 2.

While systemic actions entailed industry-wide carving out of obligations to foreign creditors, loan restructuring, purchase of NPLs, etc., specific measures were taken when systemic ones failed to produce desired results. They included debt-to-equity swaps, P&As, recapitalization, and/or management replacement. In case the financial indicators continued to deteriorate, problematic banks would be placed in bankruptcy or liquidation.

Establishing a specialized financial institution to apply the planned bank rehabilitation measures was seen as an optimal solution. This new institution would also serve as a pay-box to reimburse the depositors of failed banks. To stop further accumulation of losses in the banking sector and enable the implementation of final measures to reform the economy and halt the inflation, by the end of 1989, Yugoslav Federal Executive Council proposed the Law on the Federal Agency for Deposit Insurance and Bank Rehabilitation.³¹⁴

The law was enacted on 20 December 1989, along with the Law on Securing Resources for Establishment and Operations of Federal Agency for Deposit Insurance and Bank Rehabilitation (Federal DIA Law), and the Law on Rehabilitation, Bankruptcy and Liquidation of Banks and Other Financial Institutions.³¹⁵

Deposit insurance, as a relatively new concept in Yugoslav banking industry, was meant to increase financial stability by making the reformed financial safety net more sustainable, reassuring individual depositors of the safety of their bank savings and preventing contagious bank runs. The role of the DGS would be to minimize or eliminate risk of losses to depositors in case of a bank failure. Its primary objective is to protect unsophisticated depositors, such as households or small businesses, who cannot be expected to make any reasonably precise estimate of their bank's risk-taking appetites at all times.³¹⁶

Starting from 1991, banks were required to insure household deposits with DIA or another insurer. At the start, a little over a quarter of registered banks opted for

³¹⁴ Federal Executive Council of the SFRY (1989). *Predlog za donošenje Zakona o Agenciji federacije za osiguranje depozita i sanaciju banaka, sa predlogom da se donese po hitnom postupku*, Belgrade.

³¹⁵ Law on the Federation Agency for Deposit Insurance and Bank Rehabilitation; Law on providing funds for the establishment and operation of the Federation Agency for Deposit Insurance and Bank Rehabilitation, *Official Gazette of SFRY*, No. 84/89, p. 84.

³¹⁶ Ketcha, N. J. Jr. (1999). Deposit insurance system design and considerations, *Policy Paper*, No. 7, Basel: Bank for International Settlements, p. 223.

the deposit guarantee scheme operated by the DIA, and even fewer actually paid the premiums into the Deposit Insurance Fund. The main reason for this was the ongoing dissolution of former Yugoslavia, but also the banks' reluctance to apply the regulations which called for insuring household deposits in foreign currencies even though they were already guaranteed by the Government. At the end of 1991, Yugoslav DIA managed to collect less than 10 per cent of the planned deposit insurance premiums, and the following year the already low accumulated funds were additionally depreciated by hyperinflation.³¹⁷

The hyperinflation crisis, which culminated in late 1993, was overcome in 1994, after the implementation of a set of economic measures, including the release of new dinar. Yugoslav DGS insured household deposits in banks, with coverage limit of 5,000 dinars per depositor - the equivalent of USD 2,500.

DGS was first activated in 2001, following the failure of eight banks.³¹⁸ Insured individuals were reimbursed up to the insurance limit. For that purpose, DIA paid 17.1 million dinars out of the Deposit Insurance Fund in 2001 alone (roughly USD 300,000).³¹⁹ Even more dramatic banking crisis was already brewing. At the start of the following year, four largest banks in the State Union of Serbia and Montenegro,³²⁰ holding over two thirds of the entire asset volume of the country's banking sector, were closed on the same day. Funds for reimbursement of the protected depositors was ensured from the Government budget and the payout started seven days after the simultaneous bank failures.³²¹

Meanwhile, DIA made important technological advances to create an exhaustive and up-to-date reporting system for banks, which facilitated the assessment of quarterly insurance premium based on reliable information about monthly deposit flows, term and currency structure of bank deposits, as well as the exact number of depositors.

³¹⁷ Vujović, M. (ed.). (2022). *Agencija za osiguranje depozita: 30 godina* (monograph), Belgrade, p. 59.

³¹⁸ Požarevačka banka ad Požarevac, Šabačka banka ad Šabac, Srpska komercijalna banka ad Niš, Stankom banka ad Beograd, Izvozna banka ad Beograd, Privredna banka Novi Sad, Valjevska banka ad Valjevo and Slavija banka ad Beograd.

³¹⁹ Deposit Insurance, Rehabilitation, Bankruptcy and Liquidation Agency. (2002). *Izveštaj o radu za 2001. godinu*, Belgrade, p. 32.

³²⁰ Beogradska banka ad Beograd, Jugobanka ad Beograd, Investbanka ad Beograd and Beobanka ad Beograd.

³²¹ Vujović (ed.). (2022), op. cit., p. 37.

The overhaul of domestic banking system, initiated in 2001, brought about a surge in banking activity and entrance of international players through privatization of state-owned banks. Bank deposit base expanded dramatically. In 2003 alone, short-term deposits grew by nearly 50 per cent, whereas long-term deposits almost doubled.³²² At the end of that year, DIA had deposit insurance contracts with 44 (out of 50) banks, and two savings and loan cooperatives.

In spite of encouraging developments, domestic DGS as a whole was far from adequate. Premium rate of 0.025 per cent of eligible deposits per quarter, set in 1994, was far too low to ensure accumulation of reserves at the mandatory target level of 20 per cent eligible deposits. In fact, it would have taken over two hundred years to reach the regulatory target of Deposit Insurance Fund reserves from levies on banks alone. More importantly, the coverage limit, which may have been sufficient in 1994, was almost negligible in 2004, as it equalled only USD 80.³²³ It was high time to reform the DGS in both regulatory and operational terms.

4. SERBIAN DGS FROM 2005 ONWARDS

In 2005, two important pieces of legislation were passed: the Deposit Insurance Law and the Deposit Insurance Agency (DIA) Law. DIA Law set the operation of the deposit guarantee scheme as the DIA's core activity and identified the new entity as the legal successor of the Deposit Insurance Agency established in the Yugoslav era. The Deposit Insurance Law created a regulatory backbone of an improved, more effective DGS. Firstly, although the DGS continued to insure only household deposits in banks, the coverage limit was increased to EUR 3,000 per depositor per bank. According to the DIA's data as of 31 December 2004, this amount fully covered as much as 98.7 per cent of household deposits in banks.³²⁴

Secondly, all DGS's obligations to insured depositors were explicitly guaranteed by the Government as the last resort, with other emergency financing options available, such as extraordinary premium levies, borrowing from financial institutions, etc. Unlike before, membership of all banks registered in Serbia in the DGS run by DIA was mandatory. Deposit Insurance Law also defined the types of premiums payable by member banks that included initial, regular and

³²² National Bank of Serbia. (2004). *Izveštaj o stanju u bankarskom i ukupnom finansijskom sistemu zemlje za 2003. godinu*, Belgrade, p. 27.

³²³ Deposit Insurance, Rehabilitation, Bankruptcy and Liquidation Agency. (2005). *Izveštaj o radu Agencije u 2004. godini*, Belgrade, p. 18.

³²⁴ *Ibid*, p. 12.

extraordinary contributions. Premiums were assessed on the basis of eligible deposits, with the quarterly rate increased from 0.025 to 0.1 percent.

In terms of reimbursement and premium collections, the law distinguished between the deposits denominated in domestic and foreign currencies. All deposits in dinars would be paid back in dinars, whereas deposits in any foreign currency would be compensated in euros. In case of a bank failure, reimbursement would start no later than 30 calendar days after the date of insolvency.

Legacy of 2008 Global Financial Crisis

Acute financial market stress brought about by the Global Financial Crisis of 2007-2008 forced regulators and lawmakers around the world to review the adequacy and resilience of their financial systems. Apart from revealing the gaps in dealing with cross-border banking issues, including supervision and orderly resolution,³²⁵ the crisis also stimulated the creation of international standards for a functional deposit insurance, capable of warding off crisis contagion. In 2009, Basel Committee on Banking Supervision and the International Association of Deposit Insurers (IADI) released *Core Principles for Effective Deposit Insurance Systems* (CPs)³²⁶ for jurisdictions worldwide to use as a model and reference when assessing the quality of their DGSs.

According to the 2009 CPs, a credible DGS, which avoids distortions that may result in moral hazard, is a part of a well-constructed financial safety net, usually comprising prudential regulation and supervision, a lender of last resort and deposit insurance.³²⁷

Serbia's response to the Global Financial Crisis was timely and resolute. In 2008, the Deposit Insurance Agency Law was amended to allow the DIA to take a variety of stabilizing and reactive measures to contain potential crisis in all, rather than only state-owned banks (coverage of potential losses, purchase or assumption management of NPLs, etc.). Such measures would be taken in agreement with the remaining safety-net players, namely, the National Bank of Serbia as the bank supervisor, and the Government. These interventions were

³²⁵ International Monetary Fund (2014). *Cross-Border Bank Resolution: Recent Developments*. *IMF Board Paper*, Washington, DC: IMF, p. 2.

³²⁶ Basel Committee on Banking Supervision; International Association of Deposit Insurers (2009). *Core Principles for Effective Deposit Insurance Systems*, Basel: BIS.

³²⁷ *Ibid.*, p. 1.

intended to prevent the domino effect in case of a single bank crisis and preserve public confidence in the banking system.

Amendments to the Deposit Insurance Law were even broader in scope. The coverage limit was raised from EUR 3,000 to EUR 50,000 per depositor per bank to align it with the regional standards at the time. In addition to individual depositors or households, the DGS would also protect entrepreneurs and SMEs, which was meant to halt the deposit outflow from banks³²⁸ and reconvince depositors that they would not suffer the consequences of any bank distress.

Reimbursement delay was shortened from 30 to no more than 3 days from bank failure, while the timeframe was limited to 3 years. This meant that the DIA would have to start the payout 3 days after a bank's court-declared bankruptcy. The 3-year limit made sense as the law specified payout through an agent bank as the method of choice. While a DGS which makes direct payments to insured depositors (e.g. by mailing cheques) can have full control over the timeframe, reimbursement through an agent bank requires some action by depositors themselves, who must be given a reasonable timespan to withdraw their money. However, the 3-day start indicated technical and operational preparedness of the DGS to react on short notice and pay due balances to depositors, having subtracted their due cash commitments to the bank (netting method).

To put this into perspective, EU member states were obliged to reimburse depositors within 20 business days (which could be extended to 30 days). Outside Europe, legal obligations generally included a specific timeframe following bank failure or the receipt of information from the liquidator upon reconciliation and verification of deposits subject to payout (India and Indonesia), while others had established a timeframe from various triggers (Japan, Mexico and Russia). The legally required timeframe to pay out depositors ranged from "as soon as possible" in Canada and the USA to up to a year in Turkey. In many jurisdictions, the deposit insurers were not legally required to reimburse depositors within any specific timeframe (e.g., Australia, Brazil, Hong Kong, Korea, Singapore).³²⁹

³²⁸ In the course of 2008, over EUR 1 billion in household deposits was withdrawn from Serbian banks.

³²⁹ Financial Stability Board (2012). *Thematic Review on Deposit Insurance Systems, Peer Review Report*, Basel: FSB, p. 26.

Table 1. Comparative overview of some European DGS core features in 2008

Jurisdiction	Coverage limit	Scope of coverage	Reimbursement timeframe
Italy	EUR 103,291	Natural and legal persons (with some exceptions)	20 working days with possible 10-day extension
Greece	EUR 100,000	Natural and legal persons (with some exceptions)	20 working days with possible 10-day extension
Hungary	EUR 50,000	Natural and legal persons (with some exceptions)	ASAP
Russian Federation	EUR 20,000	Natural persons	14 days
Croatia	EUR 56,000	Natural and legal persons (with some exceptions)	30 days
Bosnia and Herzegovina	EUR 10,000	Natural persons	As decided by bank supervisor
Macedonia	EUR 20,000	Natural persons	3 months
Montenegro	Unlimited during financial crisis	Natural and legal persons	As decided by central bank

Source: DIA Serbia³³⁰

Legal Reform of 2010

The global crisis of 2007-2008 triggered many important structural changes in the banking sector, as it revealed substantial weaknesses in the banking systems and prudential frameworks, which led to excessive lending and risk-taking. Regulators responded by reforming the global prudential framework and enhancing supervision. One of the key goals was also to reduce implicit public subsidies and the impact of bank failures on the economy and taxpayers, *inter alia*, through enhanced recovery and resolution regimes.³³¹

In Serbia, authorities sought to expand the bank resolution toolkit to be able to deal more effectively with potential crises in systemically important banks. Bridge bank, a bank resolution instrument used by the FDIC since 1987, was chosen as an appropriate addition. As its name suggests, it would bridge the gap between the actual bank failure and the purchase and assumption (P&A) of the

³³⁰ Deposit Insurance Agency (2009). *Izveštaj o radu za 2008. godinu*, Belgrade, p. 12.

³³¹ Committee on the Global Financial System (2018). Structural changes in banking after the crisis, *CGFS Papers*, No. 60, Basel: Bank for International Settlements, p. 1.

bank's assets by another market player. In case of a large bank with a complex structure, P&A may be problematic given the potential lack of interested buyers in the market, especially in times of crisis. Consequently, amendments to the Deposit Insurance Law in 2010 introduced an option to use Deposit Insurance Fund (DIF) reserves to provide financial support to bridge banks or assuming financial institutions. This particular liability within the bank resolution regime was assumed by Serbian Government in 2015.

Banking Crisis of 2012-2014

However, having concluded that the available bank resolution measures were only partially efficient and provided merely short-term solutions to urgent problems, while failing to systemically stabilize the banking system,³³² in 2012, the Government proposed the Law on Assumption of Assets and Liabilities of Certain Banks to Preserve the Financial System Stability in the Republic of Serbia (Stability Law).³³³ With its application limited to the end of 2014, it allowed, *inter alia*, the use of DIF reserves to compensate the assuming bank for any difference in the value between the assumed assets and liabilities of the failed bank.

DIF funds were used in May 2012 to secure the initial capital for a bridge bank³³⁴ and provide a short-term liquidity loan. Later that year, the bridge bank also failed, and some of its assets and all liabilities (including all deposits) were transferred to an assuming bank. In compliance with the Stability Law, non-refundable financial support to the assuming bank was secured from the DIF. Following the immediate outlay of more than EUR 200 million and additional commitment to repay the remaining sum of EUR 75 million as soon as practicable, the DIF was fully depleted and would remain so until the end of 2014.

In January 2014, upon closure of a non-systemic bank,³³⁵ the selected resolution option was opening of the bankruptcy process in parallel with reimbursement of insured depositors via an agent bank. Total balance due for compensation was

³³² Government of the Republic of Serbia (2012). *Explanation of the Proposal of the Law on the Acquisition of Assets and Obligations of Certain Banks for the Purpose of Preserving the Stability of the Financial System of the Republic of Serbia*, Belgrade, p. 5.

³³³ Law on taking over assets and liabilities of certain banks in order to preserve the stability of the financial system of the Republic of Serbia, *Official Gazette of the Republic of Serbia*, No. 102/12.

³³⁴ Nova Agrobanka, established after the failure of Poljoprivredna banka Agrobanka ad Beograd.

³³⁵ Univerzal banka a.d. Beograd.

EUR 83 million. The reimbursement process started a day after the bank was placed in bankruptcy. Out of more than 50,000 depositors eligible for reimbursement, over 56 per cent were compensated within the first 10 days, and as many as 80% within the first month. Funds for depositor compensation were borrowed from the Republic of Serbia and repaid before the year-end. To achieve this, the DIA levied extraordinary premiums on banks, which paid 0.2 per cent of eligible deposits p.a. over 2014 and 2015 on top of the regular premium of 0.4 per cent p.a. With the premiums levied on banks and an IBRD loan totalling EUR 145.3 million arranged in 2014 to secure liquid funds for the DGS if required, the DIF was replenished and all its obligations were repaid in a timely fashion.

Despite the failure of five banks over the previous three years, no insured depositor in Serbia suffered any losses. In fact, except the 2014 payout case, the previous four resolution cases involved the assumption of all failed banks' liabilities (rather than covered deposits alone). In other words, even uninsured depositors were fully protected and could have access to their money at all times. This apparently strengthened public confidence in the banking system, as reflected in a steep 8.3 per cent growth of eligible deposits in 2014.³³⁶

DGS from 2015 until Present Day

Design of Serbian DGS defined by the 2015 Deposit Insurance Law³³⁷ has, in most part, remained unchanged to the present day. Starting from 2015, the coverage limit of EUR 50,000 per depositor per bank (applicable since 2008) is set as a gross balance (rather than offset against the depositor's due obligations to the bank). The scope of coverage was broadened to include micro entities (apart from individuals, entrepreneurs and SMEs) as a result of relevant amendments to the Accounting Law. Reimbursement delay was extended from three calendar days to seven business days from the opening of the insolvency proceedings against the failed bank. The designated method of reimbursement is through an agent bank, pre-selected at regular intervals.

The maximum quarterly deposit insurance premium rate was increased from 0.1 to 0.2 per cent of total eligible deposits. However, this provision was amended in 2019,³³⁸ when the basis for the premium assessment was changed from total

³³⁶ Deposit Insurance Agency (2015). *Izveštaj o radu za 2014. godinu*, Belgrade, p. 27.

³³⁷ Law on Deposit Insurance. *Official Gazette of the Republic of Serbia*, No. 14/15.

³³⁸ Law on Amendments and Supplements to the Law on Deposit Insurance, *Official Gazette of the Republic of Serbia*, No. 73/19.

eligible deposits to total covered deposits³³⁹ without any alteration of the maximum rate. The 2019 amendment was intended to better align the Deposit Insurance Law with Directive 2014/49/EU on deposit guarantee schemes.

In 2015, the target Deposit Insurance Fund was set at 5 per cent of total eligible deposits in the banking system. After the target fund has been reached, further assessment and collection of deposit insurance premiums from banks could be suspended. The 2019 amendments to the Deposit Insurance Law³⁴⁰ established a new target of 7.5 per cent of total covered deposits to be reached by 1 January 2030.

DIF reserves may be used not only for the reimbursement of protected depositors, but also for bank resolution financing within the limits set by the Banking Law (discussed in more detail under heading 6). In March 2025, the amended Banking Law designated the Resolution Fund operated by the National Bank of Serbia as the primary source of bank resolution funding. DIF's reserves may be used only in case the Resolution Fund's reserves are insufficient. Utilization of either fund is not considered as state aid to banks, since both funds are financed by contributions of Serbian banks.³⁴¹

Since 2019, deposit insurance premiums may be levied at a differential rate or by pricing the excessive bank risk into the contributions paid to the DIF. Risk-based premium assessment is a standard applied by EU DGSs and the most advanced systems in the world, such as the USA, Canada and South Korea to reduce moral hazard.³⁴² Serbian DIA has in place a methodology for assessment and collection of risk-based premiums, and is prepared to apply it in compliance with the relevant national legislation and international standards.

Currently, around 75 per cent of all deposits in domestic banking system are included in Serbian DGS. From the viewpoint of bank account balances, deposits

³³⁹ Within the meaning of the Directive 2014/49/EU on deposit guarantee schemes (EU DGSD), eligible deposits are the deposits included in DGS, whereas the covered deposits represent the part of eligible deposits that does not exceed the coverage level. In other words, a EUR 70,000 household deposit in a Serbian bank would be eligible for protection under the DGS, but only EUR 50,000 would actually be covered.

³⁴⁰ Law on Amendments and Supplements to the Law on Deposit Insurance, *Official Gazette of the Republic of Serbia*, No. 73/19.

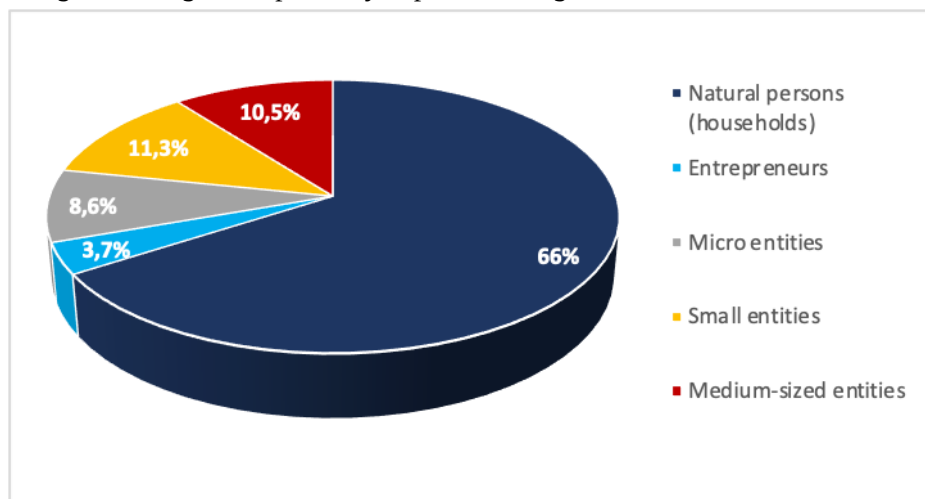
³⁴¹ Law on Amendments to the Law on Banks, *Official Gazette of the Republic of Serbia*, No. 19/25.

³⁴² Differential Premium Systems Technical Committee (2020). Evaluation of Differential Premium Systems for Deposit Insurance, *Research Paper*, Basel: IADI, p. 7.

under the coverage limit make 58 per cent of all eligible deposits. Individuals are the most dominant insured category, holding two thirds of eligible deposits, whereas no more than 3.7 per cent of eligible deposits belong to entrepreneurs (see Figure 3). As many as 99 per cent of total individual depositors are fully covered by the DGS, which means that very few persons keep more than EUR 50,000 in a single bank. This also indicates that, at present, raising the coverage limit to meet the EU-wide standard of EUR 100,000 would not make a significant difference in terms of protection of household deposits.

The DGS's design, operations and public awareness efforts have contributed to the constant increase in deposit base growth over the years (as shown in Figure 4). Concise information about the DGS and its benefits is available and easily accessible to all bank customers in print and online. In an effort to help promote financial literacy among the youth, DIA's staff regularly speak to university and high-school students, having visited 15 schools in 2024 alone.³⁴³ Services of Serbian DGS are free-of-charge to depositors, who need not take any steps to insure their money in banks. All DGS's obligations to insured depositors are fully backed by Serbian Government, while there are also many other options in place to secure the necessary funds even in the unlikely case of the DIF running out of its reserves.

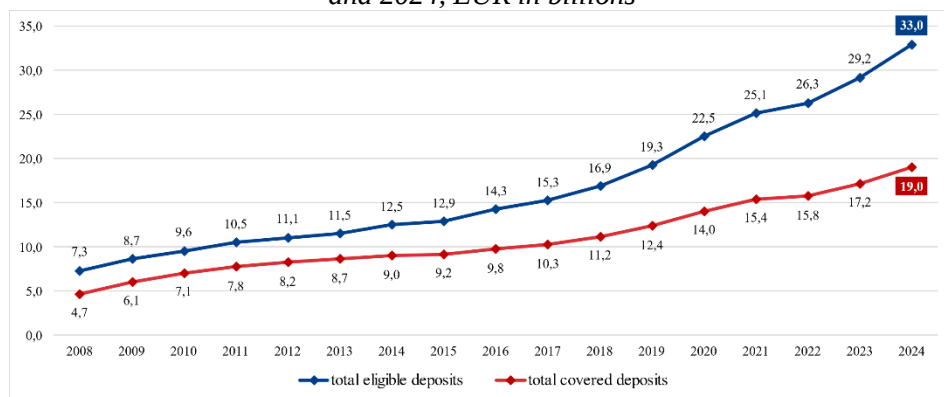
Figure 3. Eligible deposits by depositor categories as at 31 December 2024



Source: DIA Serbia

³⁴³ Deposit Insurance Agency (2025). *Izveštaj o radu za 2024. godinu*, Belgrade, p. 54.

Figure 4. Eligible and covered deposit growth trend in Serbia between 2008 and 2024, EUR in billions



Source: DIA Serbia

5. TRANSPOSITION OF EU ACQUIS

In 2015, Deposit Insurance Law was reformed within a larger compendium of national legislation in order to tackle the identified weaknesses in Serbian bank resolution system. Directive 2014/59/EU establishing a framework for the recovery and resolution of credit institutions and investment firms (BRRD) was effectively transposed in Serbian Banking Law, including the provision governing the use of DGS funds in the context of resolution (BRRD, Art. 109). In the event the resolution authority (in case of Serbia, the National Bank of Serbia) applies a resolution instrument which ensures that depositors continue to have access to their deposits, the DGS is liable for the amount of losses that covered depositors would have suffered in case the bank was placed in bankruptcy, but not in excess of what the DGS would be required to pay in case of insured depositor reimbursement. In all cases, DGS's total liability on account of a single bank resolution is limited to 50 per cent of the DIF target level.

To further improve and align the Serbian DGS with international standards and the relevant EU legislation, the Deposit Insurance Law was amended again in October 2019. The premium assessment base was harmonized with the EU 2014/49 Directive (EU DGSD) by linking it to the covered, rather than eligible deposits.

Serbian DGS is largely harmonized with the EU DGSD. Some of the major differences include the scope of coverage (EU DGSs also protect large entities) and the coverage limit, which is currently set at EUR 100,000 in the European Union.

Other distinctions include, for example, cross-border coverage of depositors at branches set up by the DGS's member institutions. In such cases, depositors at branches established by banks in other member states would be repaid by the DGS in the host member state on behalf of the home member state. To accomplish this, DGSs in EU member states have already concluded multilateral and bilateral agreements which regulate the exchange of funds and data in case of a cross-border bank failure.

Another important provision which has not been transposed in Serbian legislation so far concerns the temporary high balances. In case a deposit results from a transaction such as the sale of a private residential real estate or a life event like marriage, divorce, retirement, etc., it may enjoy temporary protection above the coverage limit for no less than three and no more than 12 months.

According to Serbia's fifth revised National Programme for Adoption of the Acquis of 24 October 2024, full transposition of the DGSD in Serbian legislation is expected by Q4 2027.

Although formally and legally in existence since 1989, during its first 15 years, DGS in Serbia was plagued by many weaknesses, as it struggled to remain relevant and credible in a society and economy in turmoil. However, its regulatory and structural base, set in 2005, has remained firm for 20 years now, with periodic re-designs in response to potential threats to financial stability. The most important changes occurred in 2008, when the insurance limit and scope of coverage were substantially increased. With technological advances, the reimbursement delay was progressively shortened to make sure the depositors covered by the DGS suffer no losses or major distress in case of a banking crisis. Gradual transposition of the applicable EU acquis has been the focus of regulatory reforms for over a decade. With the majority of the provisions of the Deposit Insurance Law already harmonized with the EU DGSD, the remaining divergences still include important features such as the limit and scope of coverage. They are expected to be addressed by the time of Serbia's accession to the European Union.

Chapter 11.

INNOVATIONS IN THE PENSION INSURANCE SYSTEM

The operation of the pension insurance system depends on numerous factors. Pension insurance systems financed using the "pay-as-you-go" system mostly depend on demographic, economic, and actuarial factors, while pension insurance systems financed through the "fully funded" system mainly depend on economic and actuarial factors. Operational risks exist in the functioning of both systems. The development of the pension insurance system implies strengthening of the key development factors and innovation in the organisation, structure, and management of this complex system, which is also the subject of this chapter. The aim of the chapter is to emphasise, based on the analysis, the importance of innovation when it comes to pension insurance system development. The chapter consists of three sections. The first section analyses the current state and basic innovations applied in global pension insurance systems. The second section presents the results and new elements in the compulsory pension insurance system in the Republic of Serbia, while the third section focuses on the state and changes in the voluntary pension insurance system in the Republic of Serbia.

1. STATE AND KEY INNOVATIONS IN GLOBAL PENSION INSURANCE SYSTEMS

There have been a large number of changes in the key factors influencing global pension insurance systems. Generally speaking, demographic changes can have a profound influence: declining birth rates, increased life expectancy, a decrease in the "dependency ratio" (the ratio between contributors and beneficiaries of the pension system), and so on. Moreover, there have been important changes in the economic sphere: recessions, economic inequality, social fragmentation, geopolitical risks, etc. Public pension insurance systems operating according to "pay-as-you-go" financing model more often than not face actuarial deficits due to these factors. To address these deficits, systemic changes (changing the method of financing pension benefits) are rarely implemented, while parametric adjustments (retirement age increase, changing the indexation method for pension benefits, etc.) are more frequently applied.³⁴⁴

³⁴⁴ Kočović, J., Rakonjac-Antić, T., Koprivica, M., & Šulejić, P. (2021). *Osiguranje u teroriji i praksi*. Belgrade: University of Belgrade, Faculty of Economics and Business, p. 488.

Within private forms of pension insurance, there has been a shift from defined benefit plans (DBP)³⁴⁵ to defined contribution plans (DCP). Within DBP, pension benefits are predetermined using a specific formula that includes parameters such as the employee's salary, length of service, and contribution rate. DCP are the pension insurance plan which do not initially specify the amount of pension benefit. The pension benefit depends on the amount of the funds accumulated at the time the right to a pension benefit is acquired, based on the contributions paid into the fund and the returns generated from investing those funds. Participants are the ones who bear the investment risks in DCP.³⁴⁶

Investments in equities represent a significant segment of defined contribution (DC) pension portfolios. Over the past two decades, these investments have been steadily increasing, ranging from 20% to 40% of the total pension insurance portfolio. Even though the results are somewhat better, in those situations pension markets are more sensitive to volatility in financial markets.³⁴⁷ The optimal strategy is for regulators not to define overly conservative investment strategies, and to protect participants by allowing them to go back to more conservative investment options, which offer lower but more stable returns, if there are poor results.

In 2024, 22 largest pension insurance markets (Australia, Brazil, Canada, Chile, China, Finland, France, Germany, Hong Kong, India, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, South Africa, South Korea, Spain, Switzerland, the United Kingdom, and the United States) accumulated approximately \$58.5 billion, representing approximately 68% of their GDP (Table 1 and Figure 1). About 91% (or \$53.51 billion) of these assets were accumulated in seven major pension insurance markets (the United States, Japan, Canada, the United Kingdom, Australia, the Netherlands, and Switzerland). Compared to 2023, in 2024 there was a slight increase of just under 5% (\$55.87 billion). The largest pension insurance market, the USA (\$37.992 billion), accumulated 64.9% of the total funds on the 22 largest global pension insurance markets in 2024 (Table 1). The Switzerland pension insurance market in 2024 accumulated 152.06% of the GDP (Figure 1).³⁴⁸

³⁴⁵ OECD (2023). *Pension Markets in Focus 2023*. Paris: OECD Publishing.

³⁴⁶ Rakonjac-Antić, T. (2024). *Penzijsko i zdravstveno osiguranje*. Belgrade: University of Belgrade, Faculty of Economics and Business, p. 42.

³⁴⁷ OECD (2024). *OECD Pensions Outlook 2024: Improving Asset-backed Pensions for Better Retirement Outcomes and More Resilient Pension Systems*. Paris: OECD Publishing, p. 10.

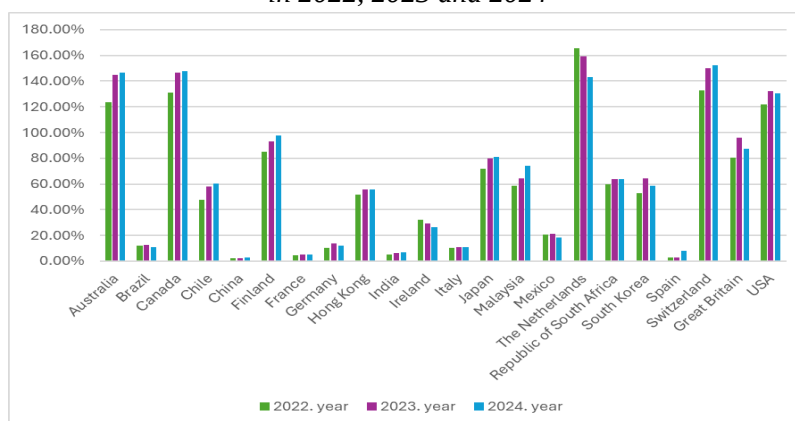
³⁴⁸ Thinking Ahead Institute (2025). *Global Pension Assets Study 2025*, www.thinkingaheadinstitute.org/research-papers/global-pension-assets-study-2025/, pp. 1-8.

Table 1. Accumulated pension fund assets by country in 2022, 2023, and 2024

Country	Pension fund assets (billion USD)		
	2022	2023	2024
Australia	2,137	2,448	2,639
Brazil	233	272	232
Canada	2,880	3,105	3,267
Chile	148	199	198
China	382	423	480
Finland	240	284	299
France	125	155	166
Germany	415	596	556
Hong Kong	190	216	224
India	173	241	270
Ireland	166	172	149
Italy	205	243	258
Japan	3,099	3,385	3,300
Malaysia	254	278	326
Mexico	291	381	342
Netherlands	1,641	1,737	1,747
Rep. of South Africa	245	243	257
South Korea	921	1,102	1,098
Spain	36	43	142
Switzerland	1,074	1,361	1,433
Great Britain	2,568	3,206	3,139
USA	30,439	35,600	37,992
Total:	47,862	55,688	58,511

Source: www.thinkingaheadinstitute.org

Figure 1. Percentage of Accumulated Pension Fund Assets in GDP by country in 2022, 2023 and 2024



Source: www.thinkingaheadinstitute.org

The most significant innovations in global pension insurance systems are the following ones: the growing need for defining more appropriate ways of managing investment risks within pension insurance systems; increased focus on health, ecosystem, and financial security for the elderly; greater involvement of the insured in making investment decisions and taking on risks through unit-linked pension insurance model; the integration of insurance, pension, and banking savings systems; the use of both human and artificial intelligence to improve administration and achieve better outcomes in pension insurance systems; emphasising the importance of a retirement plan or timely creation of income strategy that users will rely on when they retire (referred to as financial planning); searching for the forms of providing lifetime income (with a holistic approach as the focus); strengthening personalised solutions; creating stronger connections to ensure better outcomes in the pension system through collaborative efforts of all participants in the chain: the insured (contributors), pension beneficiaries, potential insurers/contributors, employers, pension plan sponsors, pension plan management companies, financial advisors, regulatory bodies, etc.³⁴⁹ Pension funds, in developed markets, have played an important role for decades due to a greater number of debt and equity securities, and derivatives as well. The increased volatility of interest rates and stricter supervision are key reasons why pension funds have encouraged the aforementioned development of financial markets. Due to growing global macroeconomic uncertainties, geopolitical, and systemic risks, pension funds have increasingly focused on alternative investments, such as real assets (real estate, land, collectables, etc.), aiming not only to diversify their portfolios and increase returns³⁵⁰ but, in certain cases, to preserve the value of their assets.³⁵¹

There have been significant changes in the global pension insurance market, particularly regarding the investment policies of pension funds, resulting from the expansion of technological innovations, artificial intelligence, and machine learning.³⁵² The impact of artificial intelligence on making adequate investment decisions is immensely important in many aspects. Major innovations have occurred in using artificial intelligence to strengthen pension plan management processes. The interaction among key participants (the insured, pension beneficiaries, pension plan sponsors, pension plan management companies, regulatory bodies, and others) is improving and accelerating. Administrative tasks and costs are decreasing. Intelligent virtual assistants are being implemented to enhance the information exchange process between system

³⁴⁹ www.mercer.com, www.ey.com

³⁵⁰ www.thinkingaheadinstitute.org

³⁵¹ Rakonjac-Antić (2024), op. cit., pp. 105-106.

³⁵² Hayman, G. (2024). *Pensions in the Age of Artificial Intelligence*. CFA Institute, p. 3.

participants, send electronic requests, and improve system control to isolate unauthorised processes and the like. The significance of artificial intelligence is particularly evident in helping the insured to plan and ensure financial security for their retirement years. It plays a key role in retirement planning; that is, creating a retirement preparation plan (a sample plan is shown in Table 2) and simulation scenarios using "what-if" analysis.³⁵³

It is essential for participants to take a proactive approach to retirement planning.³⁵⁴ Financial security during the retirement period should be planned long before being entitled to receive a pension. If a retirement plan is made early, it is more likely to be far more successful. The effectiveness of a retirement plan depends on several factors. Particular attention should be paid to carefully considering the needs during the retirement period and exploring ways to secure financial resources for the future. Moreover, one should consider the potential for investing funds, which, depending on the length of the investment, may lead to higher accumulated amounts for pension benefits

Table 2. Retirement preparation plan

	Future needs in \$ (or in €)
Estimated Expenses	
Rent and utility services	
Food	
Transportation	
Travel and leisure	
Medical services	
Other expenses	
Total expenses	
Estimated Income	
Social insurance	
Employer-sponsored pension insurance	
Interim result (sum of the two previous items)	
Additional required income	
Total income	

Source: Rakonjac-Antić (2024), *op. cit.*, p. 290.

Experts in pension insurance suggest that every individual should: a) understand their future needs as a retiree; b) learn about the benefits offered by the national social security program; c) get acquainted with pension plans sponsored by employers; d) focus on contributing to "tax-advantaged" pension plans; e) avoid

³⁵³ Rakonjac-Antić (2024), *op. cit.*, pp. 289-293.

³⁵⁴ Hugh, J. (2022). *Planning and Preparing for Reretirement*. Cardiff, p. 5.

withdrawing savings before retirement; f) start saving for retirement immediately, set goals, and stick to them; g) respect the basic principles of investing; h) constantly ask questions related to their pension plan, etc.³⁵⁵

Changes in labour markets and the emergence of new jobs, including informal ones (e.g., bloggers, influencers, etc.), have led to the introduction of micro pensions in many systems. These are voluntary, flexible pension schemes with defined contributions and the results are recorded in the individual pension accounts of the insured. Micro pensions are primarily aimed at the informal sector, individuals with low incomes, self-employed workers, and small businesses (e.g., those with up to three employees). These plans do not have a plan sponsor, and it is up to a participant to voluntarily save over a longer period. Unlike the organised, formal sector, employees in the informal sector do not officially retire (i.e., when they meet the usual age criteria required to access their funds from voluntary individual pension plan, that age can be considered as the start of retirement), but they still face the need to ensure financial security for the later years of their lives when their earning capacity will likely decrease (that is, when they get older). The pension schemes are tailored to their specific conditions, and in most cases, these employees have lower and irregular earnings.³⁵⁶

There are significant economic pressures (such as issues in the economy, inflation, unemployment, etc.) as well as demographic pressures (such as ageing populations and low fertility rates in many countries, etc.) on pension systems in certain countries. As a response to these challenges, and to increase transparency, efficiency, and security in managing pension systems, there has been ongoing research into the possibility of integrating blockchain technology into pension system management (for example, pilot projects have already been implemented in Germany and Great Britain). The possibility of integrating the optimisation and simplification of business processes with the use of integrated data is being explored. The data can be utilised in a decentralised, transparent, and secure way when needed.³⁵⁷

³⁵⁵ Rakonjac-Antić (2024), op. cit., pp. 289-290.

³⁵⁶ Iwelumo, M., & Olanipekun, T. (2017). Micro Pensions: The New Frontier. *Advisory Outlook*, PwC, pp. 1-2. In Sub-Saharan Africa, around 80% of the population is not covered by pension insurance. There is a high level of unemployment, savings mechanisms are not well established, and wages are low. Micro pensions are one of the solutions to ensure financial security for the population in older age.

³⁵⁷ Kovács, D., Molnár, B., & Weininger, V. (2024). Blockchain-Enabled Pension System Innovations: A Hungarian Case Study on Business Process Management Integration. *Computers* 2024, 13, 345, pp. 2-35, <https://doi.org/10.3390/computers.13120345>

A certain number of countries, in addition to setting a minimum pension benefit, have been using for a while other mechanisms to prevent and reduce poverty among pension insurance beneficiaries (e.g., social, universal pensions, etc.). Some countries, such as certain former Yugoslav republics (Macedonia and Croatia), have relatively recently adopted these mechanisms. Social pensions are actually the transfers from the budget or general tax revenues and are not connected to contributions. These pensions can be defined as universal (paid to individuals once they reach a certain age, along with perhaps fulfilling one more requirement regarding the number of years of residence in the country) or pensions that involve setting the income level of potential beneficiaries. There is a prerequisite regarding a maximum income level (the amount of pension benefit), and there may be restrictions regarding property ownership.³⁵⁸ Since 2019, Macedonia³⁵⁹ and Croatia, since 2021³⁶⁰, have provided social (state) pensions for the elderly. In Macedonia, the basic condition for receiving a social pension is that individuals must be over 65 years old and citizens of North Macedonia for at least 15 years before acquiring the right to a social pension. Furthermore, they must not possess personal property or property rights that would provide some kind of support, nor be beneficiaries of pensions or another form of support from another country based on age, disability or some other kind of support. If a person over 65 lives in a marital or common-law partnership with another person who is over 65, only one of them is entitled to the pension. The amount of the social pension is approximately 100 euros. In Croatia, the national benefit for the elderly can be received by individuals over 65 who have had continuous residence in the country for at least 10 years³⁶¹ prior to applying. The applicant must not be a pension beneficiary, the household must not receive an income exceeding 309 euros per household member (twice the amount of the national benefit for the elderly), and the individual must not be using social assistance, social accommodation, etc. In March 2024, 12,703 beneficiaries received the national benefit for the elderly (76.49% women and 23.51% men). Starting from 1st January, 2025, the national benefit for the elderly will amount to 154.5 euros.³⁶²

³⁵⁸ Holzmann, R., & Hinz, R. (2005). *An international perspective on pension systems and reform: Old age income support in the 21st century*. Washington, DC: The World Bank, p. 2.

³⁵⁹ The Decree of the Proclamation of the Law on Social Security for the Elderly, *Official Gazette of the Republic of North Macedonia*, No. 104 of 23.5.2019.

³⁶⁰ The National Benefit for the Elderly, *Official Gazette of the Republic of Croatia*, No. 62/2020.

³⁶¹ Law on Amendments to the Law on the National Benefit for the Elderly, *Official Gazette of the Republic of Croatia*, No. 156/23.

³⁶² <https://www.mirovinsko.hr>

2. RESULTS AND INNOVATIONS IN THE COMPULSORY PENSION INSURANCE SYSTEM IN THE REPUBLIC OF SERBIA

As mentioned in the introduction of the chapter, the operation of the public pension and disability insurance system is influenced by economic, demographic, and actuarial factors. The average pension, which is calculated using a point-based formula,³⁶³ in the Republic Pension and Disability Insurance Fund of the Republic of Serbia in 2024 amounted to 46,138 dinars (approximately 60% of pension insurance beneficiaries received a pension below the average pension level). The "replacement ratio" (the ratio of average pension to average wage) was 47.0%. The "dependency ratio" (the ratio between contributors and beneficiaries of the pension system) in 2024 was 1.7:1. There were 2,832,893 contributors and 1,657,549 pension insurance beneficiaries in the Republic Pension and Disability Insurance Fund. The pension and disability insurance fund for employed individuals is the largest one in the Republic Pension and Disability Insurance Fund. In 2024, it had 2,382,087 contributors and 1,410,793 pension beneficiaries (the "dependency ratio" was 1.7:1). The average pension for beneficiaries in the fund for the employed amounted to 48,855 dinars. The highest "dependency ratio" of 3.1:1 was in the pension and disability insurance fund for the self-employed (363,892 contributors and 116,783 pension beneficiaries), and the average pension in this fund amounted to 43,038 dinars. The worst "dependency ratio" was in the pension and disability insurance fund for farmers, with a ratio of 0.7:1 (86,914 contributors and 129,973 pension beneficiaries), and the lowest pension amount of 19,966 dinars.³⁶⁴ It is evident that there is a need to seek solutions to redefine the pension and disability insurance fund for farmers, since farmers have seasonal incomes that are unstable and largely depend on weather conditions, which is one of the key reasons for the abovementioned poor parameters. The Fiscal Council suggests that the pension provision for farmers should be removed from the compulsory pension insurance system and transferred to the social protection system.³⁶⁵ Since 2023, the contribution rate in the public pension insurance system has been 24% (14% of the employee's gross earnings and 10% by the employer).³⁶⁶ According to the financial plan for 2025,

³⁶³ A pension (pension benefit) is calculated as the product of the personal point and the general point (as of December 2024, the general point has amounted to 1,492.58 dinars).

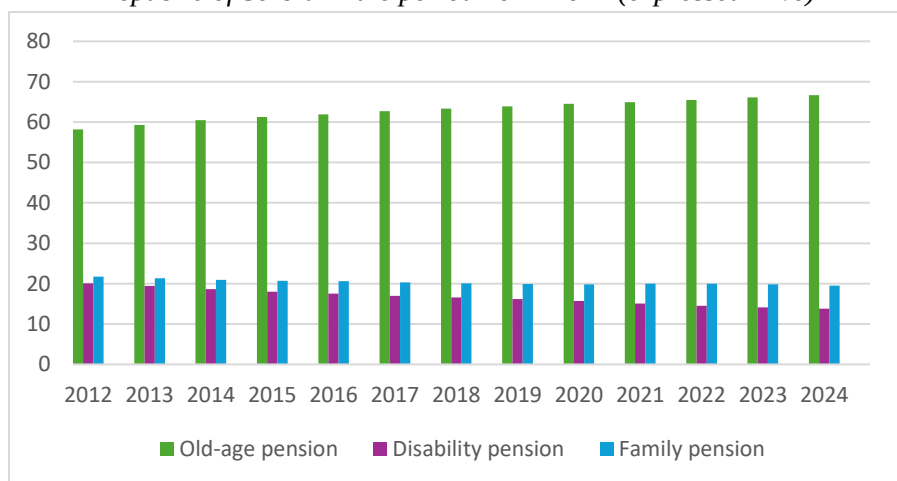
³⁶⁴ Pension and Disability Insurance Fund of the Republic of Serbia (2025). *Statistical Annual Bulletin 2024*, Belgrade, pp. 1-16.

³⁶⁵ www.paragraf.rs

³⁶⁶ Law on Contributions for Compulsory Social Insurance, *Official Gazette of the Republic of Serbia*, No. 84/2004, 10/2022, and 6/2023, article 44.

the total revenues of the Republic Pension and Disability Insurance Fund are projected to amount to 948.1 billion dinars (78%) from contributions, and 267.5 billion dinars (22%) from budget transfers, meaning that the system is not economically self-sufficient.³⁶⁷

Figure 2. Structure of pension insurance beneficiaries according to types of pensions in the Republic Fund for Pension and Disability Insurance of the Republic of Serbia in the period 2012-2024 (expressed in %)



Source: *Pension and Disability Insurance Fund of the Republic of Serbia (2025), op. cit., p. 5.*

The three basic rights that can be achieved within the public (compulsory) pension insurance system are: the right to old-age and early old-age pensions, the right to disability pension, and the right to family pension. The majority of beneficiaries are those who achieve the right to an old-age pension. In 2024, they represented 66.7% of the total number of insurance beneficiaries (Figure 2). In 2025, male insured individuals can qualify for an old-age pension at the age of 65 with at least 15 years of insurance coverage, or 45 years of insurance coverage, regardless of age. Female insured individuals can qualify for an old-age pension at the age of 63 years and 10 months with at least 15 years of insurance coverage, or 45 years of insurance coverage, regardless of age. In 2025, the right to early old-age pension is entitled to both male and female insured individuals with 40 years of insurance coverage and at least 60 years of age. The right to early old-age pension was first introduced in 2015. That year, 7,962 pension insurance

³⁶⁷ www.pio.rs

beneficiaries became entitled to it. By the end of 2024, the number of beneficiaries increased to 75,215.³⁶⁸

Compared to 2012, when the participation of disability pensioners was 20.1% of the total number of pensioners, in 2024, there was a decrease in the number of disability pensioners to 13.8%. The participation of pensioners who are entitled to a family pension in 2024 was 19.5%. This represents a slight decrease compared to 2012, when the participation accounted for 21.7% (Figure 2). The number of new pension beneficiaries, which refers to all insured individuals, in 2024 amounted to 94,090. There were 87,856 permanent pension terminations, and the net increase in pension insurance beneficiaries was 6,234 (Figure 3).

Figure 3. Number of new pension beneficiaries and number of permanent pension terminations per year in the Republic Fund for Pension and Disability Insurance in the Republic of Serbia in the period 2012-2024



Source: *Pension and Disability Insurance Fund of the Republic of Serbia (2025), op. cit., p. 17.*

So far, two methods have been used to reduce poverty among beneficiaries in the public pension insurance system: redistribution within the pension insurance system through the lowest pension institute and the mechanism of tracking and adjusting pension movements with economic developments in the country via pension adjustment (indexation). In addition to these two mechanisms, one-time

³⁶⁸ Pension and Disability Insurance Fund of the Republic of Serbia (2025). *Glas osiguranika*, LVI (3), p. 3.

payments have also been made to pension beneficiaries. Pension insurance systems more often than not utilise automatic adjustment mechanisms. These mechanisms define in advance the limits to which parameters can extend and specify corrections. Through the automatic adjustment mechanism, financial imbalances can be avoided, and consistency can be established between decision-makers and participants in the system.³⁶⁹

Article 80 of the Law on Pension and Disability Insurance³⁷⁰ and Article 27 e of the Law on Budget System³⁷¹ in the Republic of Serbia stipulates that if the total pension expenditures and the amount as an increase for pensions are less than 10% of GDP, pensions will be adjusted based on the change in the average wage excluding taxes and contributions. If the total pension expenditures and the amount as the increase for pensions are between 10% and 10.5% of GDP, pensions will be adjusted to a combination of half a percentage of change in the average wage excluding taxes and contributions, and half a percentage of change in consumer prices. If the total pension expenditures and the amount as the increase for pensions are equal to or higher than 10.5% of GDP, pensions will be adjusted according to the changes in consumer prices. Starting with the pension for December of the current year, pension adjustments are made depending on the percentage share of the pension amount and the amount of the increase in pension funds paid during the third and fourth quarters of the previous year and the first and second quarters of the current year, in the GDP for the specified period.³⁷² Currently, in the Republic of Serbia, total pension expenditures and the monetary amount as the increase for pensions are between 10% and 10.5% of GDP, therefore, pension adjustments are made based on a combination of half a percentage of change in consumer prices and half a percentage of change in the average wage excluding taxes and contributions. Starting from 1st December, 2024, the adjustment will be by 10.9%.³⁷³

In the process of implementing the Poverty Reduction Strategy, as well as within the framework of the National Strategy on Ageing for the period 2006-2015, it

³⁶⁹ De Tavernier, W., & Boulhol, H. (2021). Automatic Adjustment Mechanisms in Pension Systems. In: *Pensions at a Glance 2021: OECD and G20 Indicators*, Paris: OECD Publishing.

³⁷⁰ Law on Pension and Disability Insurance, *Official Gazette of the Republic of Serbia*, No. 34/2003-86/2019, 62/2021, 138/2022, 76/2023, 94/2024, article 80.

³⁷¹ Law on Budget System, *Official Gazette of the Republic of Serbia*, No. 54/2009, 118/2021, 92/2023, 94/2024, article 27 e.

³⁷² Law on Pension and Disability Insurance, *Official Gazette of the Republic of Serbia*, No. 34/2003-86/2019, 62/2021, 138/2022, 76/2023, 94/2024, article 80.

³⁷³ www.pio.rs

was suggested to introduce a social pension system. It would be provided to elderly individuals without income who cannot qualify for a regular pension. Occasionally, this proposal is communicated to the public by certain officials, but without a detailed elaboration on the conditions for obtaining the social pension or its amount. It is estimated that between 150,000 and 200,000 people over the age of 65 in the Republic of Serbia have no income. The number of women without income is much higher compared to men.

In recent years, IT support has been intensified on the website of the Republic Fund for Pension and Disability Insurance through the implementation of an electronic service. An e-counter has been set up, enabling the electronic submission of requests for granting pension and disability insurance rights, issuing certificates, etc. Furthermore, an e-calculator for pension projection has been installed on the website of the Republic Fund for Pension and Disability Insurance. It is also possible to submit requests for gaining information regarding insurance periods, etc.³⁷⁴

3. CHANGES IN THE VOLUNTARY PENSION INSURANCE SYSTEM IN THE REPUBLIC OF SERBIA

The voluntary pension insurance system has been gradually developing since the adoption of the Law on Voluntary Pension Funds and Pension Plans in 2005, with the majority of provisions applied in 2006.³⁷⁵ Amendments to the Law on Voluntary Pension Funds and Pension Plans were made in 2011, and since then, for 14 years, there have been no changes to the legal framework. Over the past years, the net assets of voluntary pension funds have increased slightly. The exception was 2022, when the net assets of voluntary pension funds (48.2 billion dinars) were lower by about 1.8% compared to 2021 (49.1 billion dinars).³⁷⁶ In 2023, the net assets of voluntary pension funds amounted to 53.8 billion dinars³⁷⁷, which is an increase of 11.5% compared to the net assets of voluntary pension funds in 2022 (48.2 billion dinars) (Figure 4). Due to the return on investment of 3.906 billion dinars, the net assets of voluntary pension funds had the largest

³⁷⁴ www.pio.rs

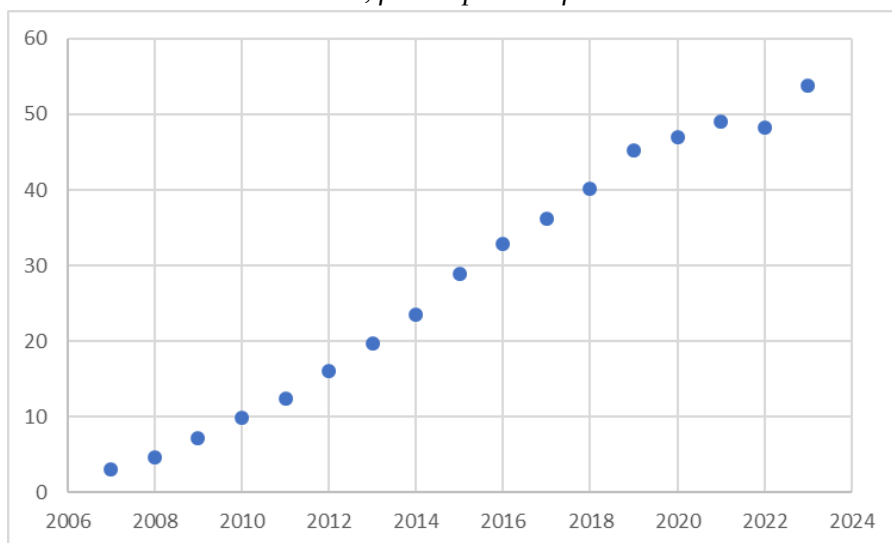
³⁷⁵ Law on Voluntary Pension Funds and Pension Plans, *Official Gazette of the Republic of Serbia*, No. 85/2005, 31/2011.

³⁷⁶ National Bank of Serbia (2023). *Voluntary Pension Funds in Serbia: Fourth Quarter Report 2022*, Belgrade, p. 4.

³⁷⁷ National Bank of Serbia (2024a). *Voluntary Pension Funds in Serbia: Fourth Quarter Report 2023*, Belgrade, p. 4.

increase.³⁷⁸ The total amount of fees obtained from contribution payments amounted to 94.5 million dinars, and the management fee was 633.4 million dinars.³⁷⁹ Generally speaking, the share of voluntary pension funds in the balance sheet total in the financial sector was insignificant, around 1%.

Figure 4. Net assets of voluntary pension funds in the Republic of Serbia, in billion dinars, for the period of 2007-2023



Source: National Bank of Serbia (2008-2024). *Voluntary Pension Fund Sector in Serbia - annual reports by year for the period of 2007-2023*, Belgrade.

FONDex, the index representing the weighted average return of all pension funds, accounted for 9.8% in 2023. Since the introduction of voluntary pension insurance in the Republic of Serbia until 2023, FONDex averaged 7.4%. In 2022, the worst result of FONDex was recorded at -2.2%. The best result, 16.6%, was achieved in 2015 (Table 3). Most of the investments were made in government bonds, accounting for around 70.1% of the assets. The remaining 17.8% was invested in custodial accounts and term deposits with banks, while investments in stocks accounted for 10.8%.³⁸⁰

³⁷⁸ Total contributions amounted to around 4,600 million dinars (about 694 million dinars more than in 2022), while withdrawals totalled around 2,685 million dinars (about 844 million dinars less than in 2022).

³⁷⁹ National Bank of Serbia (2024b). *Annual Financial Stability Report 2023*, Belgrade, pp. 86-87.

³⁸⁰ National Bank of Serbia (2024a), op. cit., p. 5.

Table 3. FONDEX (2014-2024)

Year	Return (%)
2014	11.4
2015	16.6
2016	7.7
2017	4.7
2018	5.5
2019	7.1
2020	1.0
2021	1.3
2022	-2.2
2023	8.1
2024	9.8

Source: National Bank of Serbia (2008-2024). The Voluntary Pension Fund Sector in Serbia, annual reports for the period of 2007-2023, Belgrade.

Since 2013, four companies have been operating in the voluntary pension insurance market, managing the assets of seven voluntary pension funds. Three companies manage the assets of two funds each (with different investment policies), while one company manages the assets of a single fund. In 2023, there were approximately 220,000 insured individuals in the voluntary pension insurance system³⁸¹ (an increase of about 5,000 insured individuals compared to the previous year), who had around 305,000 membership contracts. Only about 36% of insured individuals actively made contributions in 2023. In 2023, funds were held in two custodial banks³⁸² (compared to one custodial bank in 2022³⁸³).

Most commonly, when an insured person reaches the age stipulated by law, they withdraw the funds from their pension account in a lump sum (in 2023, the share of lump-sum payments in total payments was 80.7%). These lump-sum payments are generally not that high, which does not reflect the essence of this type of insurance, and it is to provide financial security to the population after retirement over a longer period of time.

In 2025, employers will be exempt from paying personal income tax and contributions for compulsory social insurance on contributions up to the amount of 8,449 dinars.³⁸⁴ Contributions made by the employer via administrative

³⁸¹ Approximately 9.6% of the total number of employees. The average age of policyholders is 48.

³⁸² OTP Bank, Serbia and Unicredit Bank, Serbia.

³⁸³ OTP Bank, Serbia.

³⁸⁴ *Official Gazette of the Republic of Serbia*, No. 08/2025.

deduction from pay, through withholding and payment from the employee's salary, will also be exempt from paying personal income tax. Favourable tax treatment in 2007 applied to the contributions in the amount of 3,000 dinars.³⁸⁵

As for regulation, there have been revisions to certain decisions and regulations. Education is not intensive, and potential insured individuals are not sufficiently encouraged to engage in financial planning. The companies managing voluntary pension funds are making efforts to strengthen their IT systems, aiming to provide a higher quality, faster, and more accessible service. The inclusion of a larger number of insured individuals in the voluntary pension insurance system is directly correlated with improvements in the population's standard of living, better economic results in the country, the development of the financial market, the enhancement of financial literacy among the population, etc.

Global pension insurance markets have undergone substantial changes, both in compulsory pension insurance (frequent pension insurance deficits) and voluntary pension insurance (frequent shifts from DBP to DCP plans). There have been innovations in the global pension insurance markets over the past period: a more significant inclusion of insured individuals in investment decision-making and risk management ("unit-linked" pension insurance); strengthening the connection between insurance, pension, and bank savings aiming to provide lifelong income for the insured; the application of the forms which combine human and artificial intelligence to achieve better results in pension insurance systems (especially in pension plan management processes, reducing administration, etc.); emphasising the importance of pension planning (as part of financial planning) along with strengthening personalised solutions; increasing application of alternative investment forms (e.g., in real assets like real estate, land, and collectibles) due to frequent financial market crises; the rise of so-called micro pensions: voluntary, flexible pension forms mainly targeted at the informal sector and individuals with low incomes; and the introduction of social pensions and other similar methods to prevent and reduce poverty among pension insurance beneficiaries.

In Serbia, the compulsory pension insurance system is kept sustainable through contributions paid by insured individuals and their employers, as well as thanks to subsidies from the state budget. In recent years, an automatic adjustment mechanism has started to be implemented within the pension insurance

³⁸⁵ Rakonjac-Antić, T. (2017), The Possibility of the Development of Long-Term Insurance Forms in Serbia. In: *Challenges and Tendencies in Contemporary Insurance Market*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 171-183.

indexation, and IT support has been intensified (electronic checks, submitting e-requests, etc.). Voluntary pension insurance is not sufficiently developed. There is a small number of insured individuals, the accumulated contribution amounts are also insufficient, and the legal framework has not changed for 14 years. On the other hand, companies managing voluntary pension funds have improved their IT support systems

PART III

INSURANCE COMPANY PERFORMANCE, RISK AND INVESTMENT STRATEGIES

Chapter 12.

INNOVATION ON THE INSURANCE MARKET OF BOSNIA AND HERZEGOVINA

The insurance market in Bosnia and Herzegovina is facing numerous challenges, though possibilities for growth and development as well. Structural economic changes, inflation, regulatory requirements and integration with the EU market affect the development of this sector. Awareness of population, legal entities, legislative and executive branches of government, media and public sentiment of the place and role of insurance in daily life, work, society and state is changing quite slowly. Although the total premium in insurance is steadily increasing, the market still faces a low penetration of insurance compared to the European average, insufficient diversification of products and high domination of automotive insurance.

The first section of the chapter analyses economic, regulatory and competitive factors which shape the insurance market in BiH, using data (2020–2024) and comparative analyses with countries of the region. The SWOT analysis identifies crucial strengths and weaknesses, opportunities and threats, while an overview of market indicators provides a better insight into current trends and potential directions of development. Besides, the chapter discusses the role of insurance intermediaries and the need for continuous education in line with EU directives, as well as possibilities for increasing investments of insurance companies in BiH. The second section points to innovations on the insurance market of Bosnia and Herzegovina, which have been evident over the past few years, assuming a positive trend in the future.

1. CONDITIONS OF INSURANCE INDUSTRY OF BOSNIA AND HERZEGOVINA AT THE END OF 2023 AND 2024

1.1. SWOT analysis of BiH insurance market

A SWOT analysis identifies the strengths and weaknesses, as well as the opportunities and threats, for the insurance market. The results of the SWOT analysis for BiH insurance market are as follows:

- Strengths: premium growth, stable demand for automotive insurance, presence of international insurers.
- Weaknesses: low share of life insurance, regulatory discrepancy with EU directives, fragmented market with 25 insurance companies.
- Opportunities: digitalisation of the sector, development of micro-insurance, reforms of pension and health insurance, potential for partnership with banks, EU integrations and harmonisation of regulations (Solvency II, ISFR 17).
- Threats: poor awareness of insurance among citizens, legal entities, in legislative and executive branches of government, political and economic uncertainty, and inflation.

1.2. Premium on the insurance market in BiH

After a continuous growth in the pre-pandemic period until 2019, insurance companies in Bosnia and Herzegovina faced a decline in premiums of 0.83% in 2020, due to the impact of the pandemic. Still, as early as 2021, the sector recorded a significant recovery, with the premium growth of 8.19%, which allowed exceeding the premium in 2019 by 7.29%, due to the low baseline from the previous year. In 2022, despite many challenges, the insurance sector continued a positive growth trend, which amounted to 7.66% compared to 2021. The growing dynamics continued in 2023 as well, when a growth of 11.69% was recorded, while 2024 witnessed an additional growth of 10.31%, with the total premium of 1.085 billion BAM.

The dominant position in this growth is taken by automotive insurance, which accounts for 49.42% of total premiums, and a growth of 11.58% compared to the previous year. Even though voluntary non-life insurance records growth, the growth is not powerful enough to increase their share in the total premium, and it still amounts only to 18%, while comprehensive insurance of motor vehicles accounts for 14%. The mandatory automotive liability insurance dominates, with a share of 61% of the premiums of non-life insurance.

Besides, life insurance recorded a 4.16% growth in 2024, although its share in the total premium decreased compared to the previous year.

These data show that although the insurance market in BiH is continuously growing, automotive insurance remains the main segment, while other types of insurance, such as life and voluntary nonlife, still have a lower share in the total premium.

Table 1. Written premiums by classes of insurance in BiH (in BAM)

Code	Class of Insurance (000 KM)	2020	2021	2022	2023	2024	Share in total premium in %
		Premium in BiH	Premium in BiH	Premium in BiH	Premium in BiH	Premium in BiH	
01	Accident insurance	48.106	50.579	53.212	57.388	62.328	5,74
	<i>Index previous year = 100</i>	91,70	105,14	105,21	107,85	108,61	
02	Health insurance	8.852	11.819	16.760	21.230	23.212	2,14
	<i>Index previous year = 100</i>	73,10	133,51	141,80	126,67	109,34	
03	Land motor vehicles insurance	71.998	79.639	89.785	106.192	121.647	11,21
	<i>Index previous year = 100</i>	98,66	110,61	112,74	118,27	114,55	
04	Railway rolling stock insurance	21	24	14	11	25	0,00
05	Aircraft insurance	33	10	107	106	108	0,01
06	Vessel insurance	13	12	12	17	17	0,00
07	Goods in transit insurance	3.098	3.053	3.796	4.058	3.840	0,35
	<i>Index previous year = 100</i>	91,15	98,52	124,34	106,90	94,64	
08	Fire and other natural disasters insurance	31.659	33.247	36.407	40.076	46.972	4,33
	<i>Index previous year = 100</i>	101,16	105,01	109,51	110,08	117,21	
09	Other damage to property insurance	29.563	29.772	34.055	39.966	44.395	4,09
	<i>Index previous year = 100</i>	109,55	100,71	114,38	117,36	111,08	
10	Motor vehicle liability insurance	386.404	408.840	426.952	480.785	536.474	49,42
	<i>Index previous year = 100</i>	101,86	105,81	104,43	112,61	111,58	
11	Aircraft liability insurance	86	191	230	291	285	0,03
12	Vessel liability insurance	31	35	37	48	50	0,00
13	General liability insurance	11.004	12.315	14.796	16.315	15.641	1,44
	<i>Index previous year = 100</i>	107,72	111,91	120,15	110,26	95,87	
14	Credit insurance	4.642	7.810	8.517	8.021	8.651	0,80
	<i>Index previous year = 100</i>	40,61	168,25	109,06	94,17	107,86	
15	Suretyship insurance	385	361	476	485	610	0,06
16	Insurance against various financial losses	2.771	4.075	5.295	6.254	9.060	0,83
17	Legal expenses insurance	37	144	127	133	243	0,02
18	Assistance insurance	1.356	1.684	2.235	3.162	4.086	0,38
01-18	NONLIFE INSURANCES	600.059	643.608	692.812	784.537	877.643	80,86
	<i>Index previous year = 100</i>	99,29	107,26	107,64	113,24	111,87	
19.01-09	Life insurance	141.079	155.555	167.494	176.613	180.243	16,61
19.20-29	Annuity insurance	376	131	357	1.409	475	0,04
19.30-39	Additional insurance with life insurance	14.709	18.898	20.183	21.264	27.088	2,50
19.99	Other types of life insurance	222	211	211	218	0	0,00
19	LIFE INSURANCE	156.386	174.795	188.245	199.505	207.807	19,14
	<i>Index previous year = 100</i>	98,71	111,77	107,70	105,98	104,16	
01-19	NONLIFE AND LIFE INSURANCE	756.445	818.403	881.057	984.042	1.085.450	100,00
	<i>Index previous year = 100</i>	99,17	108,19	107,66	111,69	110,31	

Source: Derived from data in Statistics of the Insurance Market in BiH for 2020, 2021, 2022, 2023 and Reports of the Insurance Supervisory Agency of the Federation BiH and the Insurance Agency of RS for 2024.

In 2024, like in previous years, non-life insurance dominated the structure of insurance premiums, with an 80.86% share of the total premium. Within them, the share of the premium of automotive liability insurance was the highest, amounting to 49.42%. In 2024, the life insurance premium increased by 4.16% compared to 2023, while the premium of nonlife insurance increased by 11.87%. The share of life insurance premiums in BiH of 19.14% (decreasing by 5.57% compared to 2023) is still insufficient (in 2004 it amounted to 9.8%). In 2024, the growth of the insurance premium was achieved in both Entities in BiH.

Table 2. Premium in Bosnia and Herzegovina and Entities in the period 2016-2023 (in BAM 000)

	2016		2017		2018		2019		2020		2021		2022		2023		2024	
	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)	Premium BAM000	Market share (%)
BiH	633.944	100	683.288	100	712.832	100	762.781	100	756.445	100	818.403	100	881.057	100	984.042	100	1.085.450	100
Index	100		107,78		104,32		107,01		99,17		108,19		107,66		111,69		110,31	
F BiH	446.550	70,44	475.400	69,58	497.842	69,84	532.021	69,75	529.091	69,94	572.791	69,99	615.496	69,86	682.450	69,35	753.835	69,45
Index	100		106,46		104,72		106,87		99,45		108,26		107,46		110,88		110,46	
RS	187.393	29,56	207.888	30,42	214.989	30,16	230.759	30,25	227.354	30,06	245.612	30,01	265.561	30,14	301.592	30,65	331.615	30,55
Index	100		110,94		103,42		107,34		98,52		108,03		108,12		113,57		109,95	

Source: Derived from data in the Statistics of the Insurance Market in BiH for 2020, 2021, 2022, 2023 and 2024.

Five leading insurers on the total insurance market in BiH mostly maintained their share of ca 41% from 2016 to 2022 and recorded an 8.4% increase of share in 2023, while ten leading insurers, which had a share of 66% to 68%, recorded an increase of 4.53% in 2023. The growth of share of leading insurers continued in 2024. The dominant companies in 2024 were ASA-Central osiguranje 12%, Uniqa osiguranje 11% and Vienna osiguranje 10%.

Table 3. Concentration of the insurance market in BiH in the period 2016-2023

Share in total premium (%)	2018	2019	2020	2021	2022	2023	2024
Five leading insurers	41,94%	41.43%	41.49%	40.88%	40.87%	44.30%	45.01%
Ten leading insurers	68.91%	68.51%	68.51%	68.01%	67.69%	70.76%	71.00%
Dominant company	9.24%	8.97%	9.13%	9.08%	9.13%	9.13%	11.74%

Source: Derived from data in the Statistics of the Insurance Market in BiH for 2019, 2021, 2022, 2023 and 2024.

The life insurance market in BiH is dominated by foreign-owned insurance companies. Measured by the share in total premium of life insurance in BiH in 2024, the share of companies Uniqa, Vienna, Grawe dd (FBiH), Grawe a.d. (RS) and Triglav amounted to 88.34%, while in 2023 their share was 89.87%. Among life insurers, Vienna osiguranje d.d. (leader) and Uniqa osiguranje d.d. (next to the leader) recorded the highest premiums in 2022 and pushed Grawe osiguranje d.d. to the third place, which remained unchanged in 2024.

Table 4. Ownership structure and classes of insurance dealt with by companies in BiH as of 31.12.2023

Ownership	Nonlife	Life	Composite	Reinsurance	Total
Local	12	0	1	1	14
Foreign	3	0	8	0	11
Total	15	0	9	1	25

Source: Reports of the Insurance Supervisory Agency of the Federation BiH and the Insurance Agency of RS for 2023

Insurance companies in BiH are still fractionated (both in terms of organisation and in terms of assets and capital), and achieve very disparate effects measured by the gross written premium by companies compared to the invested capital, engaged assets and the number of employees, although there have been some positive steps in terms of increase in capital. In line with provisions of the Law on Insurance, insurance companies based in the Federation BiH were bound to increase the minimum share capital for classes of nonlife insurances from 5.0 million BAM to 10.0 million BAM, for life insurances from 3.0 million BAM to 6.0 million BAM and for reinsurance business from 3.0 million BAM to 6.0 million BAM by April of 2022. By the prescribed deadline, all the insurance companies based in the Federation BiH complied with the set capital increase.

Table 5. Premium and HHI index for the market of nonlife and life insurance in BiH in the period 2020-2024

Insurance company	I-XII-2020			I-XII-2021			I-XII-2022			I-XII-2023			I-XII-2024		
	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI
1. ASA CENTRAL osiguranje*	37.525	4,96	39	45.462	5,55	31	50.903	5,78	33	108.902	11,07	122	127.468	11,74	138
2. Adriatic osiguranje d.d.	69.098	9,13	83	74.321	9,08	82	80.448	9,13	83	95.053	9,66	93	108.758	10,02	100
3. Euroherc osiguranje d.d.	62.559	8,27	109	64.872	7,93	63	69.789	7,92	63	77.972	7,92	63	88.552	8,16	67
4. Uniqa osiguranje d.d.	62.133	8,21	67	71.300	8,71	76	74.356	8,44	71	79.291	8,06	65	83.955	7,73	60
5. Triglav osiguranje d.d.	53.527	7,08	50	60.646	7,41	55	66.544	7,55	57	74.664	7,59	58	79.858	7,36	54
6. Sarajevo-osiguranje d.d.	65.090	8,60	74	63.426	7,75	60	68.970	7,83	61	68.239	6,93	48	75.739	6,98	49
7. Grave osiguranje d.d.	54.967	7,27	53	56.481	6,90	48	57.789	6,56	43	58.899	5,99	36	61.005	5,62	32
9. Croatia osiguranje d.d.	36.440	4,82	23	39.250	4,80	23	40.200	4,56	21	44.651	4,54	21	52.046	4,79	23
10. Wiener osiguranje a.d.	28.265	3,74	14	31.775	3,88	15	36.100	4,10	17	40.017	4,07	17	46.966	4,33	19
8. Vienna osiguranje d.d.	34.471	4,56	21	35.872	4,38	19	39.503	4,48	20	48.608	4,94	24	46.336	4,27	18
11. Gawe osiguranje a.d.	32.981	4,36	19	35.649	4,36	19	37.875	4,30	18	38.998	3,96	16	40.976	3,78	14
12. Osiguranje Aura a.d.	24.811	3,28	17	27.608	3,37	11	29.142	3,31	11	32.124	3,26	11	32.990	3,04	9
13. Dunav osiguranje a.d.	23.618	3,12	10	25.963	3,17	10	28.349	3,22	10	30.701	3,12	10	32.918	3,03	9
15. Camelija osiguranje d.d.	10.886	1,44	3	16.193	1,98	4	17.016	1,93	4	24.177	2,46	6	30.118	2,77	8
17. Premium osiguranje a.d.	8.769	1,16	2	12.613	1,54	2	16.049	1,82	3	21.132	2,15	5	29.041	2,68	7
14. Dina osiguranje a.d.	23.046	3,05	15	22.137	2,70	7	22.853	2,59	7	25.895	2,63	7	27.320	2,52	6
16. Mikrofin osiguranje a.d.	11.646	1,54	4	14.193	1,73	3	16.563	1,88	4	21.531	2,19	5	24.389	2,25	5
18. Nešković osiguranje a.d.	16.235	2,15	7	16.719	2,04	4	19.089	2,17	5	19.396	1,97	4	21.380	1,97	4
19. Bečko-gas osiguranje d.d.	16.578	2,19	8	16.084	1,97	4	16.664	1,89	4	17.354	1,76	3	17.769	1,64	3
21. Osiguranje Garant d.d.	11.226	1,48	3	11.921	1,46	2	13.001	1,48	2	13.694	1,39	2	15.073	1,39	2
22. Euros osiguranje a.d.	11.135	1,47	3	11.786	1,44	2	11.741	1,33	2	12.088	1,23	2	14.944	1,38	2
23. Krajina osiguranje a.d.	4.403	0,58	1	4.239	0,52	0	5.823	0,66	0	7.715	0,78	1	13.210	1,22	1
20. Triglav osiguranje a.d.	11.153	1,47	3	11.523	1,41	2	10.952	1,24	2	17.080	1,74	3	10.392	0,96	1
24. SAS - Super P osiguranje a.d.	3.488	0,46	0	3.402	0,42	0	3.434	0,39	0	3.866	0,39	0	4.246	0,39	0
25. Central osiguranje d.d.	42.397	5,60	50	44.967	5,49	30	47.904	5,44	30	1.994	0,20	0	0,00	0,00	0
Total:	756.445	100	581	818.403	100	574	881.057	100	571	984.042	100	619	1.085.450	100	631

Source: Derived from data in the Statistics of the Insurance Market in BiH for 2020 and 2024

In late 2022, companies ASA osiguranje d.d. Sarajevo and Central osiguranje d.d. Sarajevo merged and in early 2023 they continued doing business under the name ASA Central osiguranje d.d. Sarajevo, which assumed the leading position in nonlife insurances business, which it maintained in 2024. It is realistic to expect consolidation of insurance companies in BiH to continue. Between 2015 and 2022, the insurance industry of the European Union recorded a decrease in the total number of insurance companies that do business on the EU market, which is a result of consolidation of financial institutions (in the merger and acquisition

processes) aimed at improving competitive advantage and market position, i.e. increase in profit, achieving greater efficiency and protection of business risks.

On the insurance market in BiH there is a high level of competition, particularly on the market of nonlife insurances. The entire insurance market in BiH is not concentrated, as confirmed by values of HHI³⁸⁶ which are considerably lower than 1,000, although the share of the five leading players is growing (45.01% in 2024). Within the total insurance market, the nonlife insurance market in BiH is also unconcentrated.

Table 6. HHI index for the non-life insurance market in BiH in the period 2020-2024

Insurance company	I-XII-2020			I-XII-2021			I-XII-2022			I-XII-2023			I-XII-2024		
	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI
1. ASA Central osiguranje*	37.525	6,25	39	45.462	7,06	50	50.903	7,35	54	108.902	13,88	193	127.468	14,52	211
2. Adriatic osiguranje d.d.	64.550	10,76	116	68.034	10,57	112	72.644	10,49	110	86.539	11,03	122	100.873	11,49	132
3. Euroherc osiguranje d.d.	62.559	10,43	109	64.872	10,08	102	68.970	9,96	99	77.972	9,94	99	88.552	10,09	102
4. Sarajevo-osiguranje d.d.	61.416	10,23	105	60.215	9,36	88	62.711	9,05	82	64.229	8,19	67	71.565	8,15	66
5. Triglav osiguranje d.d.	32.210	5,37	29	32.972	5,12	26	39.250	5,67	32	45.220	5,76	33	46.675	5,32	28
6. Wiener osiguranje a.d.	25.653	4,28	18	29.117	4,52	20	34.956	5,05	25	37.384	4,77	23	44.118	5,03	25
7. Croatia osiguranje d.d.	32.110	5,35	29	35.173	5,46	30	35.696	5,15	27	39.597	5,05	25	42.732	4,87	24
8. Uniqa osiguranje d.d.	28.414	4,74	22	30.740	4,78	23	30.815	4,45	20	34.829	4,44	20	39.809	4,54	21
9. Osiguranje Aura a.d.	24.811	4,13	17	27.608	4,29	18	29.142	4,21	18	32.124	4,09	17	32.990	3,76	14
10. Dunav osiguranje a.d.	23.618	3,94	15	25.963	4,03	16	28.349	4,09	17	30.701	3,91	15	32.918	3,75	14
11. Camelija osiguranje d.d.	10.886	1,81	3	16.193	2,52	6	19.089	2,76	8	24.177	3,08	9	30.118	3,43	12
12. Premium osiguranje a.d.	8.769	1,46	2	12.613	1,96	4	17.016	2,46	6	21.132	2,69	7	29.041	3,31	11
13. Drina osiguranje a.d.	23.046	3,84	15	22.137	3,44	12	22.853	3,30	11	25.895	3,30	11	27.320	3,11	10
14. Grawe osiguranje d.d.	25.911	4,32	22	25.960	4,03	16	25.759	3,72	14	26.236	3,34	11	25.828	2,94	9
15. Mikrofin osiguranje a.d.	11.646	1,94	4	14.193	2,21	5	16.664	2,41	6	21.531	2,74	8	24.389	2,78	8
16. Nešković osiguranje a.d.	16.235	2,71	7	16.719	2,60	7	16.563	2,39	6	19.396	2,47	6	21.380	2,44	6
17. Bečko-gas osiguranje d.d.	16.578	2,76	8	16.084	2,50	6	16.049	2,32	5	17.354	2,21	5	17.769	2,02	4
18. Osiguranje Garant d.d.	11.226	1,87	3	11.921	1,85	3	11.741	1,69	3	13.694	1,75	3	15.073	1,72	3
19. Euros osiguranje a.d.	11.135	1,86	3	11.786	1,83	3	10.952	1,58	2	12.088	1,54	2	14.944	1,70	3
20. Grawe osiguranje a.d.	9.959	1,66	18	10.779	1,67	3	11.130	1,61	3	13.084	1,67	3	14.294	1,63	3
21. Krajina osiguranje a.d.	4.403	0,73	1	4.239	0,66	0	5.823	0,84	1	7.715	0,98	1	13.210	1,51	2
22. Triglav osiguranje a.d.	11.153	1,86	3	11.523	1,79	3	13.001	1,88	4	17.080	2,18	5	10.392	1,18	1
23. SAS - Super P osiguranje	3.488	0,58	0	3.402	0,53	0	3.434	0,50	0	3.866	0,49	0	4.246	0,48	0
24. Vienna osiguranje d.d.	362	0,06	29	938	0,15	0	1.399	0,20	0	1.799	0,23	0	1.937	0,22	0
26. Central osiguranje d.d.	42.397	7,07	50	44.967	6,99	49	47.904	6,91	48	1.994	0,25	0	0	0,00	0
Total:	600.059	100	668	643.608	100	603	692.812	100	599	784.537	100	685	877.643	100	709

Source: Derived from data in the Statistics of the Insurance Market in BiH for 2020 and 2024

In 2024, the life insurance market was moderately concentrated with the value of HHI index of 1655; as of 31.12.2023, the value of HHI index amounted to 1732. The five leading insurers generated 88.34% of life insurance premiums in the period 01.01.-31.12.2024.

³⁸⁶ Herfindahl-Hirschman index (HHI) is a measure of market concentration calculated by squaring the market share of each insurer and then summing the resulting numbers. The index range of 0-1000 indicates an unconcentrated market, 1000-1800 a moderate concentration, while the range of 1800-10000 indicates monopoly.

Table 7. HHI index for the life insurance market of Bosnia and Herzegovina in the period 2020-2024

Insurance company	I-XII-2020			I-XII-2021			I-XII-2022			I-XII-2023			I-XII-2024		
	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI	Premium 000 BAM	Market share (%)	HHI
1 Vienna	34.109	21,81	476	34.935	19,99	399	38.802	20,61	425	46.809	23,46	550	44.399	21,37	456
2 Uniga	33.719	21,56	465	40.560	23,20	538	43.541	23,13	535	44.462	22,29	497	44.146	21,24	451
3 Grawe (FBiH)	29.055	18,58	465	30.521	17,46	305	32.030	17,02	290	32.663	16,37	268	35.177	16,93	287
4 Grawe (RS)	23.022	14,72	217	24.871	14,23	202	24.970	13,26	176	25.914	12,99	169	26.681	12,84	165
5 Triglav (FBiH)	21.317	13,63	186	27.674	15,83	251	30.539	16,22	263	29.445	14,76	218	33.183	15,97	255
6 Croatia	4.329	2,77	8	4.077	2,33	5	3.808	2,02	4	5.053	2,53	6	9.314	4,48	20
7 Adriatic	4.549	2,91	8	6.287	3,60	13	7.804	4,15	17	8.515	4,27	18	7.885	3,79	14
8 Sarajevo	3.674	2,35	6	3.212	1,84	3	3.833	2,04	4	4.010	2,01	4	4.174	2,01	4
9 Wiener	2.613	1,67	3	2.658	1,52	2	2.919	1,55	2	2.634	1,32	2	2.848	1,37	2
Total:	156.386	100	1832	174.795	100	1720	188.245	100	1716	199.505	100	1732	207.807	100	1655

Source: Derived from data of the Insurance Supervisory Agency of the FBiH and the Insurance Agency of RS

1.3. Insurance premium by sales channels

Besides their own sales channel, insurance companies increasingly sell insurance policies through insurance intermediaries who, in the name and on behalf of the company, conclude insurance contracts (insurance agents) or connect the company with the insurance beneficiaries with the aim of making an insurance contract (insurance brokers).

Table 8. The number of insurance intermediaries in BiH in 2023

	BiH	FBiH	RS
Intermediaries – natural persons	1.614	1007	607
Insurance agents	1.591	998	593
Insurance brokers	23	9	14
Intermediaries – legal persons	85	62	23
Agency companies	59	42	17
Brokerage companies	26	20	6
Total	1.699	1069	630

The total premium generated through insurance intermediaries in Bosnia and Herzegovina has a share of about 41% of the total generated premium, with a tendency towards further growth.

These data indicate an important role of insurance intermediaries in the process of sales and distribution of insurance products. Intermediaries play a crucial role in connecting insurance beneficiaries with insurance companies and provide them with professional knowledge and services related to choosing and signing insurance policies.

In 2023, the total premium generated through insurance intermediaries amounted to BAM 407,893,857, which translates into 41% of the total amount of premium. Out of the total amount of premium generated through insurance intermediaries, BAM 373,158,636 or 91% refers to premium generated through insurance agents, while 9% was generated through insurance brokers. Out of the total premium generated through insurance agents, 22% of premium or BAM 81,759,387 was generated through bank sales channel (life insurances of BAM 64.6 million, credit insurance of BAM 4.9 million, accident insurance of BAM 7.05 million, and property insurance of BAM 205 million).

With respect to types of insurance, 66% of the total premiums generated through intermediaries pertain to non-life insurance, while life insurances account for 34% of the premiums. Out of the total amount of life insurance premium, companies generated BAM 114,291,570 or 70% through intermediaries, while they generated BAM 60,055,301 or 30% of the total life insurance premiums through their own network.

Table 9. Overview of written premiums by sales channels in 2023

Class of insurance	Own sales network	Share in total premium	Agents	Share in total premium	Brokers	Share in total premium
Accident insurance	36.042.527	63%	15.803.122	28%	5.542.585	10%
Health insurance	15.636.806	74%	4.167.339	20%	1.425.865	7%
Land motor vehicle insurance	67.004.041	63%	36.905.504	35%	2.282.443	2%
Railway rolling stock insurance	8.040	100%	0	0%	0	0%
Aircraft insurance	104.999	99%	0	0%	1.050	1%
Vessel insurance	14.754	85%	0	0%	2.504	15%
Goods in transit insurance	2.842.413	70%	377.288	9%	837.993	21%
Fire and other natural disasters insurance	28.360.612	71%	6.208.918	15%	5.506.567	14%
Other damage to property insurance	25.468.499	64%	5.749.763	14%	8.747.644	22%
Motor vehicle liability insurance	322.353.863	67%	155.808.357	32%	2.622.813	1%
Aircraft liability insurance	243.201	84%	39.585	14%	8.305	3%
Vessel liability insurance	37.365	78%	10.234	21%	314	1%
General liability insurance	10.200.691	63%	1.487.960	9%	4.618.190	28%
Credit insurance	1.943.943	24%	4.964.079	62%	1.112.593	14%
Suretyship insurance	391.878	81%	93.073	19%	0	0%
Insurance against various financial losses	3.227.850	52%	1.344.505	21%	1.681.623	27%
Legal expenses insurance	120.266	91%	10.432	8%	2.162	2%
Assistance insurance	2.080.072	66%	967.888	31%	113.909	4%
NONLIFE INSURANCES	516.081.821	66%	233.938.045	30%	34.506.560	4%
LIFE INSURANCES	60.055.297	30%	139.220.589	70%	228.661	0%
NONLIFE AND LIFE INSURANCES	576.137.118	59%	373.158.635	38%	34.735.221	4%

The insurance sector of the Federation of Bosnia and Herzegovina continuously grows and develops, facing numerous challenges and changes. Therefore, continuous education of players on the insurance market becomes crucial for

maintaining high standards and adjusting to new market requirements, particularly in providing quality services to insurance clients. In this respect, it is necessary to begin permanent education of insurance intermediaries and, by their professional training, ensure an additional impact on the increased growth of the insurance portfolio and achieve a quality change in the structure of the total insurance portfolio in favour of voluntary types of insurance.

These principles and practices are included in the general framework of insurance directives and regulations of the European Union such as the Insurance Distribution Directive (IDD), which recommends that insurance and reinsurance intermediaries, employees of insurance and reinsurance companies and employees of insurance and reinsurance intermediaries should comply with continuing professional training and development in order to maintain an adequate level of performance, and the obligation to establish a mechanism of assessing knowledge and expertise of the listed participants on the insurance market. By means of the Stabilization and Association Agreement, Bosnia and Herzegovina became bound to implement structural reforms necessary for the unobstructed functioning of the internal market, which implies a gradual harmonisation of regulations with the European acquis.

Education is aimed at raising the professional level of intermediaries and other players in the insurance sector, improving service quality, increasing financial literacy and strengthening trust in the insurance market.

1.4. Competitive position of the insurance sector of BiH compared to the surroundings

Table 10 shows values of the selected macroeconomic indicators in BiH for the period 2016-2023.

Table 10. Overview of macroeconomic indicators and insurance premium in BiH

Indicator	2016	2018	2019	2020	2021	2022	2023
Nominal GDP (in million BAM)	29,904	33,444	35,296	34,240	38,637	45,505	51,699
Real GDP (growth rate in %)	3.2	3.7	2.8	-3.2	7.5	4.1	1.6
Consumer price index	-1.1	1.4	0.6	-1.0	2	14.0	6.1
Foreign debt of gov. sector as % of GDP	29.7	24.5	23.1	25.5	24.8	20	17.1
Total premium in BiH (in million BAM)	634	713	763	756	818	881	984
Share of premium in GDP in %	2.1	2.1	2.2	2.14	2.12	1.94	1.90

Source: Agency for Statistics of BiH, Central Bank of BiH

Compared to developed European countries, the economy of BiH and the insurance sector within it are insufficiently developed and considerably lag behind the average of the EU member countries by: gross domestic product, written premium, the share of total premium in gross domestic product, GDP per capita and the amount of premium per capita. Thus, in 2023, penetration of insurance in BiH amounted to 1.9%, while at the same time the Republic of Croatia recorded the share of insurance premiums in GDP of 2.29%.

Comparative indicators of insurance density also indicate an insufficient development of the local insurance industry in BiH.

Table 11. Comparative indicators for the EU countries, surrounding countries and BiH in 2023

	EU	Serbia	Montenegro	BiH
Number of insurance companies	4.333*	16	9	24
Total premium (million eur)	1.084.152	1.329	119	503
Out of total, life (million eur)	548.594	262	24	102
Premium/capita (euro)	2.277	201	189	147
Out of it, life/capita (euro)	1.168	40	37	30
Out of it, nonlife/capita (euro)	1.109	161	152	117
Premium share in GDP (%)	6,20	1,92	1,74	1,9

Source: Insurance Supervisory Agency of the FBiH, Insurance Agency of RS, Agency for Statistics of BiH, Insurance Supervisory Agency of Montenegro, Statistical Office of Montenegro - MONSTAT, National Bank of Serbia, Statistical Office of the Republic of Serbia, Swiss Re, Insurance Europe

Table 12. Comparative indicators for some European countries and BiH for 2017-2023

Country	I-XII-2017 I-XII-2018			I-XII-2019		I-XII-2021			I-XII-2022			I-XII-2023		
	Premium per capita (in \$)	Premium (mil. \$)	Premium (mil. \$)	Premium share in GDP (%)	Premium per capita (in \$)	Premium (mil. \$)	Premium share in GDP (%)	Premium per capita (in \$)	Premium (mil. \$)	Premium share in GDP (%)	Premium per capita (in \$)	Premium (mil. \$)	Premium share in GDP (%)	Premium per capita (in \$)
United Kingdom	3.810	336.510	366.243	10,30	4.362	399.142	11,1	5.273	363.009	10,5	4.781	374.936	9,7	4.759
Germany	2.687	241.485	243.852	6,33	2.934	275.779	6,5	3.313	241.633	5,9	2.881	245.464	5,5	2.910
Switzerland	6.811	59.384	58.953	8,38	6.835	57.793	7,1	6.610	56.082	6,9	6.364	61.187	6,9	6.830
Sweden	3.672	37.092	38.385	7,22	3.729	47.955	7,6	4.597	54.363	9,3	5.180	44.201	7,4	4.185
Austria	2.217	20.392	19.710	4,42	2.219	22.186	4,6	2.480	20.447	4,3	2.262	21.993	4,3	2.418
Czech Republic	609	7.067	7.215	2,83	677	8.259	2,9	771	8.541	2,9	791	9.698	2,9	881
Slovenia	1.184	2.765	2.819	5,05	1.354	2.206	5	1.047	2.948	4,7	1.396	3.302	4,86	1.562
Croatia	333	1.570	1.583	2,64	391	1.842	2,7	473	1.771	2,6	456	1.838	2,31	479
Serbia	123	978	973	1,93	140	1214	1,9	177	1.200	1,9	177	1.437	1,92	216
BiH	112	416	436	2,19	125	474	2,12	137	480	1,86	140	556	2,03	162

Note: Premium for BiH was calculated based on the average value of dollar which amounted to 1.769982 at the end of 2023.

Source: Central Bank of Bosnia and Herzegovina, Insurance Supervisory Agency of the FBiH, Insurance Agency of RS, Swiss Re

In 2023, insurance density in Croatia amounted to 454 Euro (in 2022 it amounted to 436 Euro) per capita, while the EU average in 2023 amounted to 2,277 Euro per capita.³⁸⁷

The poor competitiveness of the insurance sector results from the overall unsatisfactory position of BiH.

1.5. Insurance premiums and paid claims

In 2023, ASA - Central osiguranje assumed the leading position in terms of written premiums and the amount of paid claims. The leading position was maintained in 2023, with the share in total premium of 12%, and a 14% share in total paid claims. The leading insurance company by the written premium in 2020, 2021 and 2022 in BiH was Adriatic osiguranje d.d. The leading insurance company by paid claims in BiH in 2021 and 2022 was Uniqa osiguranje, while in 2020, Sarajevo osiguranje d.d. was the leading company by the total amount of paid claims.

Table 13. Relationship between paid claims and total premium by insurance companies in BiH in 2020, 2021, 2022, 2023 and 2024

No.	Insurance company	I-XII-2020			I-XII-2021			I-XII-2022			I-XII-2023			I-XII-2024		
		Value of paid claims	Premium	Paid claims/Pr emium	Value of paid claims	Premium	Paid claims/Pr emium	Value of paid claims	Premium	Paid claims/Pr emium	Value of paid claims	Premium	Paid claims/Pr emium	Value of paid claims	Premium	Paid claims/Pr emium
1	ASA Central osiguranje*	16.523.607	37.525.194	44,03	21.741.114	45.462.206	47,82	25.682.777	50.903.123	50,45	51.196.007	108.901.959	47,01	65.830.468	127.467.964	51,64
2	Uniqa osiguranje d.d.	25.364.312	62.132.760	40,82	37.559.245	71.300.223	52,68	39.531.623	74.356.208	53,17	43.918.497	79.291.068	55,39	38.609.292	83.955.160	45,99
3	Adriatic osiguranje d.d.	27.490.073	69.098.199	39,78	29.475.914	74.321.317	39,66	29.953.819	80.447.864	37,23	35.079.784	95.053.499	36,91	47.078.187	108.757.965	43,29
4	Sarajevo-osiguranje d.d.	33.940.487	65.095.076	52,14	33.246.343	63.426.493	52,42	33.183.440	66.544.308	49,87	34.937.138	68.239.037	51,20	36.082.469	75.738.826	47,64
5	Grave osiguranje d.d.	26.307.662	54.966.613	51,50	29.801.875	56.400.095	52,76	32.482.414	57.789.147	56,21	34.546.971	58.698.584	58,65	34.305.094	61.004.550	56,23
6	Euroherc osiguranje d.d.	23.834.589	62.558.646	38,10	25.209.898	64.872.243	38,86	27.792.736	68.970.115	40,30	28.853.603	77.972.369	37,00	34.424.168	88.551.887	38,87
7	Triglav osiguranje d.d.	22.943.896	53.527.136	42,86	24.611.252	60.645.654	40,58	26.812.647	69.789.165	38,42	27.511.903	74.664.468	36,85	30.806.880	79.858.271	38,58
8	Croatia osiguranje d.d.	24.018.095	36.439.504	65,91	22.665.111	39.249.808	57,75	23.682.710	39.503.435	59,95	23.801.671	44.650.502	53,31	26.304.925	52.046.048	50,54
9	Gravac osiguranje a.d.	13.095.697	32.981.129	39,71	13.750.137	35.649.481	38,57	17.595.697	36.099.623	48,74	21.706.436	38.997.615	55,66	20.040.110	40.975.759	48,91
10	Vienna osiguranje d.d.	11.642.810	34.470.835	33,78	14.120.072	35.872.270	39,36	20.926.355	40.200.202	52,06	21.315.182	48.607.630	43,85	25.285.023	46.336.141	54,57
11	Wienner osiguranje a.d.	11.665.137	28.265.163	41,27	12.026.986	31.775.147	37,85	19.150.730	37.874.910	50,56	20.302.939	40.017.447	50,74	16.536.242	46.965.928	35,21
12	Dunav osiguranje a.d.	9.741.186	23.617.908	41,24	9.947.650	25.962.680	38,32	12.814.724	28.348.516	45,20	13.097.977	30.701.352	42,66	14.089.624	32.918.135	42,80
13	Osiguranje Aura a.d.	6.385.993	24.810.885	25,74	7.436.667	27.608.309	26,94	11.022.954	29.141.837	37,83	10.604.269	32.124.042	33,01	11.716.675	32.989.722	35,52
14	Draza osiguranje a.d.	7.870.305	23.045.841	34,15	8.324.791	22.137.155	37,61	9.430.711	22.863.473	41,27	9.325.815	25.885.450	36,01	9.017.966	27.318.704	33,01
15	Mikrofin osiguranje a.d.	4.825.195	11.645.609	41,43	4.412.176	14.192.989	31,09	7.014.518	16.663.832	42,09	7.787.094	21.531.139	36,17	9.734.842	24.388.917	39,92
16	Brčko-gas osiguranje d.d.	6.015.892	16.578.043	36,29	5.869.224	16.083.806	36,49	7.551.953	16.048.664	47,06	7.642.831	17.354.011	44,04	7.170.451	17.769.270	40,35
17	Camelijo osiguranje d.d.	3.170.856	10.885.612	29,13	4.784.396	16.193.011	29,55	6.203.296	19.088.711	32,50	7.434.540	24.177.161	30,75	9.832.617	30.118.185	32,65
18	Nešković osiguranje a.d.	5.732.877	16.235.462	35,31	4.761.606	16.718.775	28,48	4.775.560	16.563.145	28,83	6.283.926	19.396.013	32,40	6.526.940	21.379.606	30,53
19	Premium osiguranje a.d.	1.706.666	8.768.640	19,46	2.883.501	12.612.568	22,86	4.699.639	17.016.393	27,62	5.803.000	21.131.582	27,46	7.067.911	29.041.318	24,34
20	Triglav osiguranje a.d.	3.428.056	11.153.030	30,74	6.522.998	11.523.222	56,61	5.228.051	13.000.528	40,21	5.306.274	17.079.733	31,07	5.739.828	10.392.301	55,23
21	Euros osiguranje a.d.	2.386.215	11.135.097	21,43	3.344.860	11.786.329	29,38	3.587.766	10.952.043	32,76	4.081.057	12.088.446	33,76	4.763.711	14.944.292	31,88
22	Osiguranje Garant d.d.	3.017.594	11.225.944	26,88	3.092.374	11.920.751	25,94	4.244.655	11.740.646	36,15	3.885.077	13.093.548	28,37	4.646.204	15.073.331	30,82
23	Krojuša osiguranje a.d.	1.391.400	4.403.223	31,60	1.553.708	4.238.903	36,65	1.690.699	5.823.474	29,03	2.179.949	7.714.679	28,26	2.761.635	13.210.379	20,91
24	Central osiguranje d.d.	14.306.617	42.397.283	33,74	18.936.638	44.967.294	42,11	22.587.460	47.903.518	47,15	1.692.342	1.994.048	84,37	1.347.102	4.245.843	31,73
25	SAS - Super P osiguranje a.d.	970.599	3.487.593	27,83	865.775	3.401.603	25,45	1.001.537	3.434.223	29,16	1.126.836	3.866.495	29,14	1.347.102	4.245.843	31,73
Total:		309.775.817	756.445.024	40,95	346.944.110	818.403.122	42,39	398.648.471	881.057.103	45,25	429.411.018	984.041.877	43,64	469.718.364	1.065.449.501	43,27

Source: Statistics of the Insurance Market in BiH

The share of settled claims in total premiums in BiH in 2024 decreased by 0.83% compared to 2023, while the amount of settled claims in the same period increased by 9.39%, which was probably affected by the inflation trends in 2022, which continued in 2023 and 2024.

³⁸⁷ Croatian Insurance Bureau (2024). *Insurance Market in the Republic of Croatia 2023*. Zagreb, https://huo.hr/upload_data/site_files/trziste-osiguranja-2023.pdf

Table 14. Premium and settled claims in BiH (in BAM 000)

I-XII-2020				I-XII-2021				I-XII-2022				I-XII-2023				I-XII-2024			
	Premium	Settled claims	Settled claims/P premium	Premium	Settled claims	Settled claims/P premium		Premium	Settled claims	Settled claims/P premium		Premium	Settled claims	Settled claims/P premium		Premium	Settled claims	Settled claims/P premium	
BiH	756.445	309.776	40,95%	818.403	346.944	42,39%		881.057	398.648	45,25%		984.042	429.411	43,64%		1.085.450	469.718	43,27%	
<i>Index</i>	106	111	105	108	112	104		108	115	107		112	108	96		110	109	99	
F BiH	529.091	231.543	43,76%	572.791	262.152	45,77%		615.496	288.839	46,93%		682.450	310.278	45,47%		753.835	348.559	46,24%	
<i>Index</i>	106	112	106	108	113	105		107	110	103		111	107	97		110	112	102	
RS	227.354	78.233	34,41%	245.612	84.792	34,52%		265.561	109.809	41,35%		301.592	119.133	39,50%		331.615	121.159	36,54%	
<i>Index</i>	106	108	102	108	108	100		108	130	120		114	108	96		110	102	92	

Source: Derived from data of the Insurance Supervisory Agency of the FBiH and the Insurance Agency of RS, and Statistics of the Insurance Market in BiH

However, the share of paid claims in the total written premium in BiH is lower compared to Croatia. The lower ratio in BiH indicates a poorer user protection, though also a greater profitability of insurance companies.

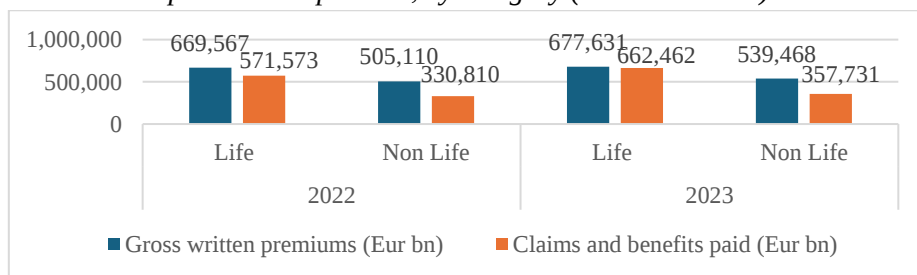
Table 15. Premium and paid claims in BiH and Croatia

	2017	2018	2019	2020	2021	2022	2023
BiH premium in BAM 000	683.288	712.832	762.781	756.445	818.403	881.057	881.057
Paid claims in BiH in BAM 000	266.772	279.268	301.170	309.776	346.944	398.648	398.648
Paid claims / Total premium in BiH	39%	39%	39%	41%	42,39%	45,25%	45,25%
Paid claims / Total premium in Croatia	56%	56%	57,96%	50,14%	62%	61%	67%

Source: Derived from data of the Insurance Supervisory Agency of the FBiH and the Insurance Agency of RS, and Statistics of the Insurance Market in BiH

Besides, both the written premium and the share of paid claims in total insurance premiums in BiH are considerably lower compared to indicators of paid claims and premiums in the European Union (see Figure 1).

Figure 1. Total value of insurance premiums written and claims and benefits paid in Europe 2023, by category (in billion euros)



Source: EIOPA- Insurance statistics

1.6. Competitiveness of the insurance sector on financial market in BiH

Compared to neighbouring countries, the insurance sector in BiH has a lower penetration and competitiveness. Croatia and Serbia record a higher share of premium in GDP, while in BiH the automotive insurance segment still dominates.

By the value of assets and capital on the financial market at the level of BiH, the insurance sector considerably lags behind the banking sector. Thus, both in 2020 and 2021 the value of assets of the banking sector was 16.14 times greater than the assets of the insurance sector. In 2022, this difference decreased by 2% compared to previous years. In 2023, the difference decreased by 0.55% compared to 2022.

Table 16. Structure of the financial services sector in BiH in the period 2017-2023

Financial institution	2017		2018		2019		2020		2021		2022		2023	
	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)	Assets (mil. BAM)	Share (%)
Banks	27.249	87,7	29.854	87,9	32.508	88,18	32.905	88,40	35.442	88,35	36.945	87,84	39.056	87,65
Index	100		109,56		108,89		101,22		107,71		104,24		105,71	
Insurance companies	1.717	5,53	1.819	5,36	1.967	5,34	2.070	5,56	2.196	5,47	2.335	5,55	2.482	5,57
Index	100		105,94		108,14		105,24		106,09		106,33		106,30	
Investment funds	855	2,75	889	2,62	855	2,32	817	2,19	935	2,33	1.070	2,54	1.044	2,34
Microcredit organizations	791	2,55	891	2,62	996	2,7	1.087	2,92	1.170	2,92	1.274	3,03	1.451	3,26
Leasing companies	260	0,84	297	0,87	324	0,88	344	0,92	374	0,93	437	1,04	525	1,18
Total	31.072	100	33.966	100	36.867	100	37.223	100	40.117	100	42.061	100	44.558	100
Index	100		109,31		108,54		100,97		107,77		104,85		105,94	

Source: Derived from data of the Central Bank of BiH

At the same time, the capital of banks in 2023 was 8.64 times greater than capital of insurance and reinsurance companies in BiH.

Table 17. Assets and capital in the banking sector and the insurance and reinsurance sector in BiH (in BAM million)

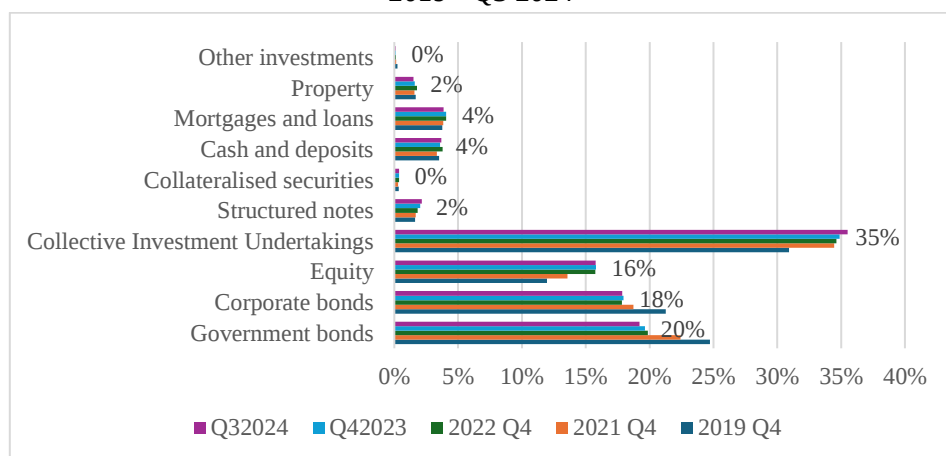
	2017		2018		2019		2020		2021		2022		2023	
	Banks	Insurance companies	Banks	Insurance companies	Banks	Insurance companies	Banks	Insurance companies	Banks	Insurance companies	Banks	Insurance companies	Banks	Insurance companies
Assets	27,25	1,72	29,85	1,82	32,51	1,97	32,91	2,07	35,44	2,20	36,95	2,34	39,06	2,48
Index	100	100	110	106	109	108	101	105	108	106	104	106	106	106
Insur/Banks		6,30%		6,09%		6,05%		6,29%		6,20%		6,32%		6,35%
Capital	3,27	0,42	3,44	0,43	3,73	0,45	4,12	0,49	4,22	0,52	4,45	0,53	4,88	0,56
Index	100	100	105	102	108	106	110	109	103	106	105	103	110	107
Insur/Banks		12,86%		12,48%		12,17%		11,85%		12,22%		11,89%		11,56%

Source: Derived from data of the Central Bank of BiH

1.7. Investments in insurance

Insurance companies are the greatest institutional investor in Europe, with over 10.63 trillion euros invested in economy in 2021.³⁸⁸ Developed market economies provide greater and more diverse possibilities for investing due to developed financial markets, which offer a large number of different kinds of financial instruments. The insurance sector is the greatest institutional investor in Europe, and is highly concentrated in a small number of countries (the United Kingdom, France, Germany, Italy). The total portfolio of insurers' investments in the EU27 increased by 4.1% in 2021, to 9.75 billion euro compared to 2020, to decrease in the fourth quarter of 2022 to 8.38 billion euro or by 14.1%, while in the second quarter of 2023 it recorded a growth of 2.7% in the amount of 8.6 billion euro, and the 3Q 2024 recorded a growth of 4.37% in the amount of 9.24 billion euro. In 2024, bonds (government and corporate) were still the main kind of assets, making up about 37% of the total portfolio. The share of equity remained at the same level and amounted to 16% of the portfolio. Figure 2 presents the portfolio of the insurance industry in the EU from the fourth quarter of 2019 to the third quarter of 2024.

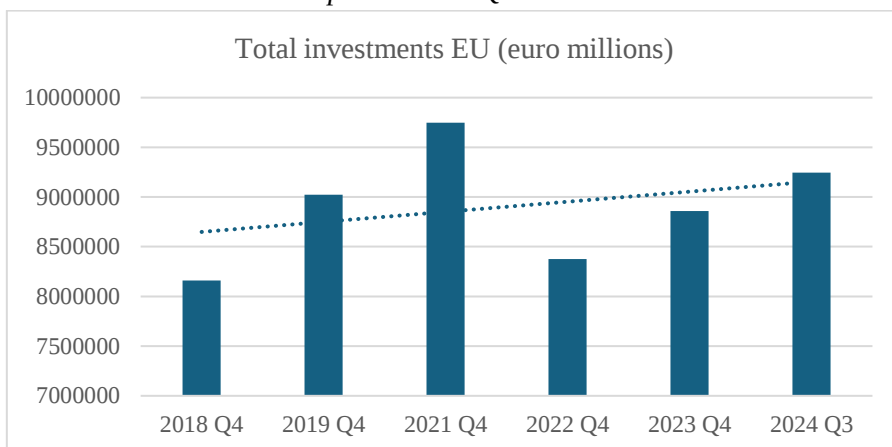
Figure 2. Investment portfolio of the insurance sector in the EU in the period 2019 - Q3 2024



Source: EIOPA (Q3 2024). EIOPA Insurance Statistics - Exposure data

³⁸⁸ Insurance Europe (2022). *Annual Report 2021-2022*. Brussels, <https://www.insurance-europe.eu/publications/2620/annual-report-2021-2022/>

Figure 3. Total investment portfolio of the insurance sector in the EU in the period 2018-Q3 2024

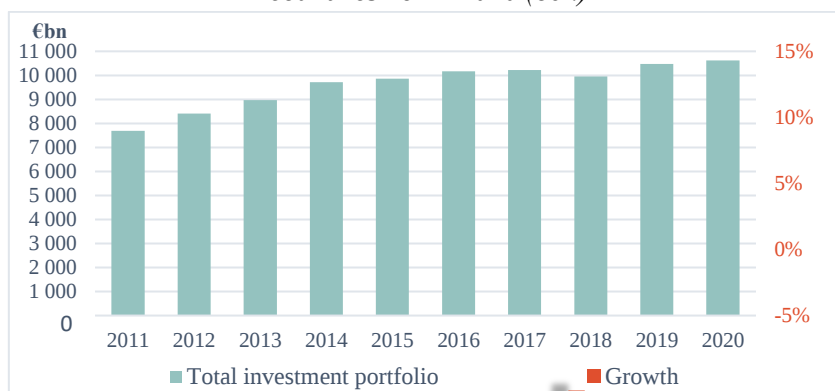


Source: EIOPA (Q3 2024), EIOPA Insurance Statistics - Exposure data

In developed economies, (re)insurance companies pay considerably more attention and corporate responsibility to maintaining liquidity and profitability of investing resources of technical reserves, mathematical reserve and guarantee fund in line with the new Solvency II regime in the European Union (EU).

The graphs below show the growth of insurance investment portfolio in 32 European countries in the period 2010 – 2020 in billion euros from 7,697 (in 2010) to 10,622 (in 2020) or by 38%.

Figure 4. Total investment portfolio of the insurance sector in 32 European countries 2011–2020 (€bn)

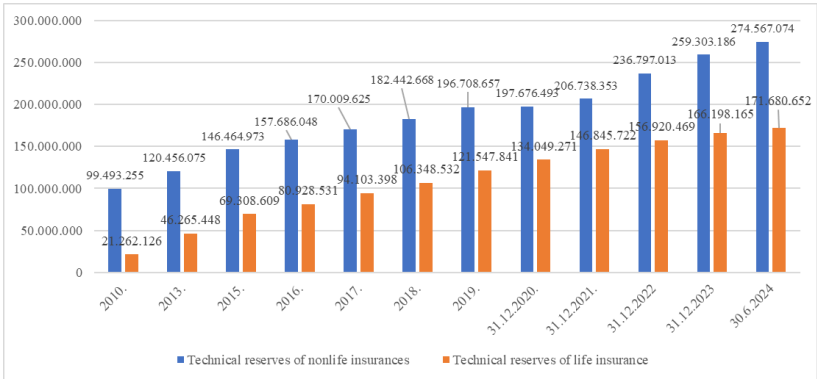


Source: Insurance Europe (2021). *European Insurance in Figures - 2020 data*. Brussels, p.52.

Insurance sector in BiH recorded a continuous growth of assets from 2015 to 2023 and is the second by share (next to banks) in the total assets of the financial sector in BiH.

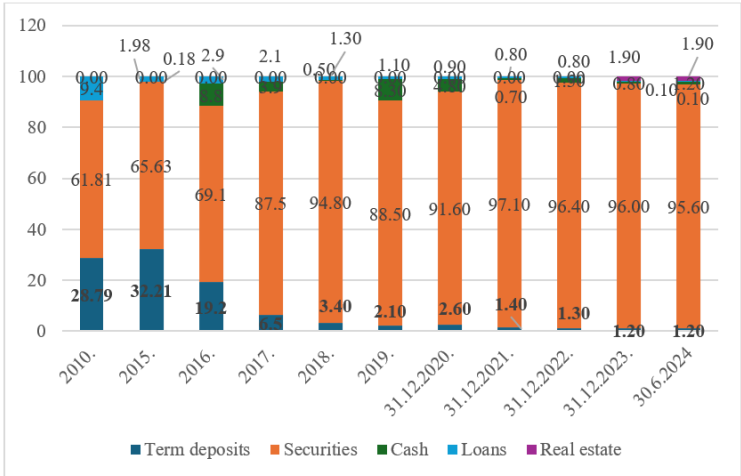
However, the total potentials of local financial institutions are very restricted and modest compared to the region and Europe. Besides, investments of insurance companies in BiH are far lower by value and differ considerably by structure from investments in the developed European economies.

Figure 5. Value of technical reserves by classes of insurance in Republika Srpska (RS) in BAM



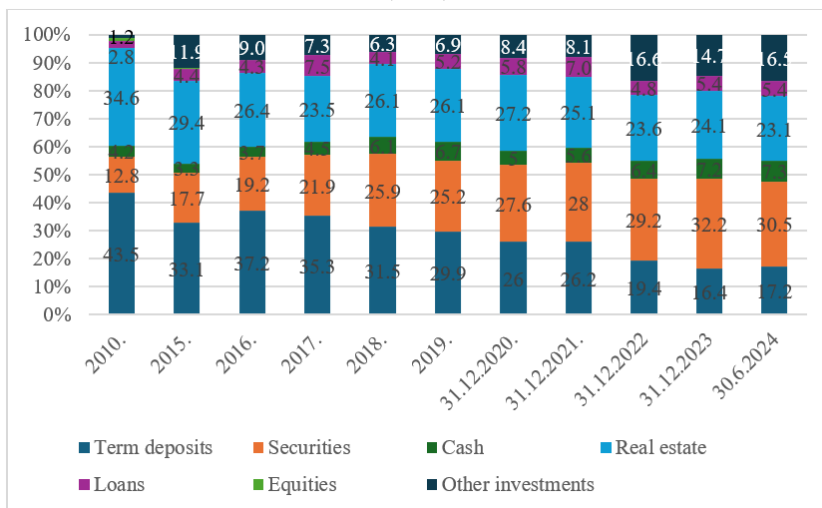
Source: Insurance Agency of the Republika Srpska (2024). Report on the state of insurance sector in the Republika Srpska in the period from 01.01.2024 to 30.06.2024. Banja Luka

Figure 6. Structure of investing life insurance technical reserves in RS (in %)



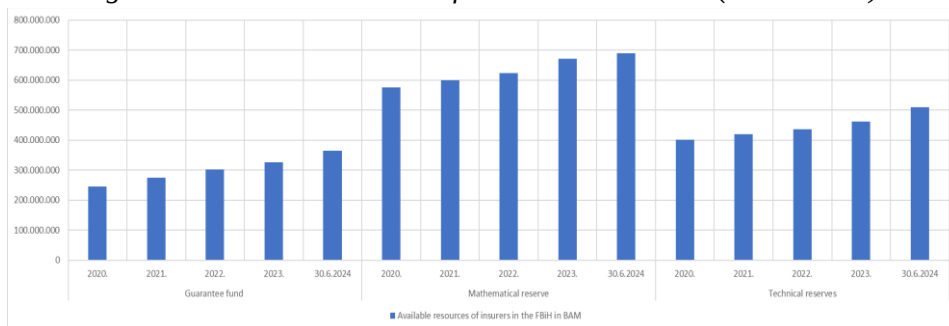
Source: Insurance Agency of the Republika Srpska (2024), op. cit.

Figure 7. Structure of investing nonlife insurance technical reserves in RS (in %)



Source: Insurance Agency of the Republika Srpska (2024), op. cit.

Figure 8. Available resources of insurers in the FBiH (in BAM 000)

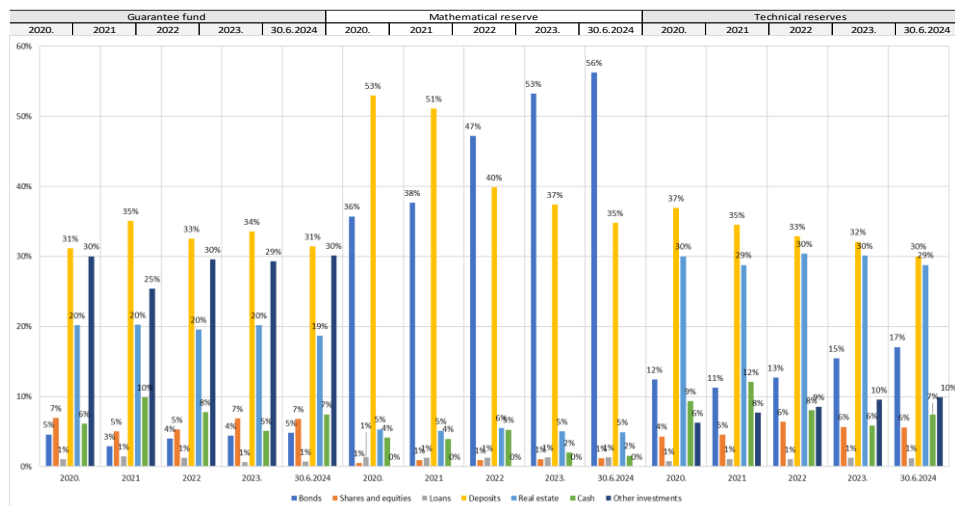


Source: Report on the Insurance Sector of the Federation BiH, Insurance Supervisory Agency of the FBiH

Comparison of the data reveals that investments of insurance companies in developed European economies are far greater by value and essentially different by the structure of investments from those in BiH.

Insurers in BiH mostly invest in government bonds and bank deposits, while on the EU markets, investments in bonds, equity and alternative instruments prevail. A lack of diversification restricts yield, stability and long-term sustainability of the sector.

Figure 9. Structure of investing resources of guarantee fund, mathematical reserve and technical reserves in the F BiH



Source: Report on the Insurance Sector of the Federation BiH, Insurance Supervisory Agency of the F BiH

2. INNOVATIONS ON THE INSURANCE MARKET OF BOSNIA AND HERZEGOVINA

Over the past several years, certain innovations on the insurance market of Bosnia and Herzegovina are evident. The chapter will briefly present the following forms of innovation on the insurance market of Bosnia and Herzegovina: new institutional forms of education, new research projects directly related to the insurance industry, increase in awareness by persons in charge of the application of upcoming artificial intelligence, new campaigns in life and nonlife insurances, other innovations.

2.1. New institutional forms of education

- Association of Insurance Companies in the Federation BiH has founded the Center for Education and Research in Insurance, which has been effectively and successfully operating since 2023. It has its legislative acts out of which, due to the character of the chapter, we single out only the Curriculum of open type, subject to permanent updating and with the annual Operational Plan. It is primarily intended for members of the insurance industry in BiH, though also for all natural and legal persons interested in insurance topics. Past participants in educational programs came from whole Bosnia and Herzegovina, both from the sphere of insurance and from the finance

industry, and gradually also include representatives of economy and independent natural persons (insurance intermediaries or those who wish to become one of them). Curriculum is synthetically divided into: Introductory Program, Basic Program and Specialist Program. All the programs have syllabi of their own, lecturers, readings and ways of knowledge assessment. For all lectures, a combination is made of the best lecturers from academic community and practitioners. Each topic is elaborated by two lecturers together: theoretical and practical aspects of the topic which is the subject of education. Knowledge assessment for all topics is optional. An appropriate certificate is granted for the success at the exam.

- (b) Insurance Supervisory Agency of the Federation BiH has a Program of mandatory professional education for taking professional exams for the insurance intermediary (agents, brokers). This educational program is also delivered by academics and practitioners.

2.2. New research projects directly related to the insurance industry

At the moment, Association of Insurance Companies of the Federation BiH is carrying out, among other things, two important research projects through its Centre for Education and Research:

- a) Application of ESG (Environmental Social Governance) principle of doing business on the insurance market. Based on a representative sample of members of the insurance industry in the Federation and BiH, the work on the project up to now has highlighted the following:
 - Insurance Agency in BiH, within the limits of its capacities, is introducing application of the ESG business principles; these principles are becoming part of responsibility of the Agency for environment, society and good governance.
 - Insurance Supervisory Agency of the Federation BiH, as a regulatory and supervisory body, points out that its activities pertain to rewriting a bylaw which prescribes limits and kind of assets in which resources of an insurance company can be invested, by introducing the term 'green assets', explaining what it implies and defining stimulating limits for it. It is also true of documents which prescribe the system of risk management in the insurance company.
 - The only reinsurance company registered in BiH, Bosna Reosiguranje d.d., in line with its capacities, is applying ESG principles.
 - Insurance companies mainly owned by institutions, foreign insurance companies (e.g. Croatia, Euroherc, Triglav, Vienna, Wiener), align their business policy in this segment with the business policy of the group they

belong to. They have begun, formally and substantially, to introduce the described principles of sustainable business.

- Market leader in the insurance sector, ASA Central osiguranje, d.d. Sarajevo has an active formal and substantial approach to the implementation of ESG criteria in its work, which ultimately results in a responsible and sustainable business. The adopted business policy opens possibilities for permanent improvements and the latest standards related to this form of responsible activity.
- Insurance companies which are mostly owned by persons from BiH (e.g Sarajevo osiguranje and Brčko –gas) have not established application of ESG principles.
- b) Perception of the insurance industry and customer satisfaction is a strategic project, important both for insurance companies and the insurance industry as a whole, and for all institutions and the entire society in BiH. Center for Education and Research of the Association of Insurance Companies of the Federation BiH implements this project in cooperation with business partner Valicon based on business collaboration and, generally, on the outsourcing model.

The degree of customer satisfaction with the work of insurance companies from the Federation BiH is determined by defined groups of insurance beneficiaries: natural persons, small, medium-size and big legal persons, state institutions, and foreign legal persons doing business in BiH. Results of this research will have multiple benefits for everybody in BiH.

2.3. Increasing awareness by persons in charge of the application of upcoming artificial intelligence

In the paper entitled “Artificial intelligence in the insurance sector”, presented at the international conference SORS (Meeting of insurers and reinsurers Sarajevo, 2025), the authors (Željko Šain, Migdat Hodžić and Suada Alić Mešanović) point to the unstoppable trend of artificial intelligence in the insurance sector. They underscore that in general, separately and individually, artificial intelligence plays an increasingly significant role in the insurance industry, bringing about many advantages in risk management, data analysis and process optimization; it allows faster and more accurate estimates, decreases human errors and increases efficiency.

In the insurance industry of BiH as well, persons in charge are increasingly aware of the importance of applying artificial intelligence. Analysis of great quantities of data, recognizing patterns and simulation of different scenarios can greatly help insurance companies avoid risk. Although artificial intelligence itself cannot

guarantee the elimination of risk, it can help in making decisions which minimise or completely remove the possibility of the emergence of certain risks.

The paper presented at SORS conference particularly underscores following: “Having in mind the increasing influence of artificial intelligence on citizens' daily life, a need arose in recent years for adopting regulatory acts, guidelines and other legal documents which ensure security, protection of human rights and spurring innovations on the digital market. Regulation of artificial intelligence through the document named *Artificial Intelligence Act – AI Act* of the European Union sets crucial guidelines for the application of artificial intelligence technologies, including the insurance industry, with the aim of ensuring a secure, transparent and fair use of technology. This framework helps in minimising risks such as discrimination, violation of privacy, avoiding any prejudice and loss of users' trust, and ensures the use of artificial intelligence in line with fundamental values of the European Union, such as human rights, security and fairness.”

2.4. New campaigns in life and non-life insurances

The overall living and working conditions in Bosnia and Herzegovina, with possible trends, bring about new or innovative risks that should be adequately recognised, assessed and institutionally processed.

In the sphere of life insurance, it is particularly true of the area of life insurance and insurance of life in all forms, which are offered by the contemporary theory and practice of the insurance industry. This time, a particular emphasis is put on annuity contracts in all modalities. It primarily refers to annuity contracts related to the third age or, in actuarial language, insurance of the delayed lifelong personal annuity. The aim of the campaign is to create a positive public sentiment about the “dignified old age” with a real financial basis. The existing form of pension insurance, based on the model of solidarity between generations, or pay-as-you-go, has become economically unsustainable and requires radical reforms. Insurance companies involved in life insurance have a solution for this existential issue for any person and society as a whole.

In the sphere of nonlife insurances attempts are made to improve the whole portfolio of this form of insurance, though a particular attention is paid, supported by a UNDP project, to the climate change risk and repercussions related to this source of risk: floods, landslides etc., suggesting that they should be covered by mandatory insurances.

2.5. Other innovations

International interest in the insurance industry in BiH is gaining new momentum. Examples include the arrival of company GrECo, a leading provider of intermediary services in insurance and corporate governance in Central and Southeast Europe, on the market of Bosnia and Herzegovina. It is an interesting fact for analysts of conditions on the insurance market. Why is an institution involved in intermediation in insurance coming to the market, instead of another institution or organisation from the insurance industry, for example, a new insurance or reinsurance company? There are certainly objective reasons for it.

* * *

The insurance market in Bosnia and Herzegovina shows signs of steady growth, though it still lags behind developed markets of the EU. It is necessary to carry out additional regulatory harmonisations, increase the penetration of voluntary insurances, and strengthen competition. Education of intermediaries, improvement of digitalisation and better market infrastructure can considerably contribute to the development of the insurance industry in BiH.

Recommendations are as follows:

- 1) Increase of penetration of insurance through education of citizens and managers in legal persons, including persons in charge in legislative and executive branches of government. Development of voluntary insurances and micro-insurance to increase market penetration.
- 2) Harmonisation of regulations with the EU (e.g. Insurance Distribution Directive), to increase stability and competitiveness.
- 3) Support for the consolidation of insurance companies with the aim of increasing efficiency.
- 4) Investment in digital platforms for more accessible services. Digitalisation and modernisation of sales channels, particularly in the area of life insurance.
- 5) Diversification of investments of insurance companies aimed at long-term sustainability. Investing the resources of insurance companies in infrastructural projects.

Strengthening regulatory capacities and more efficient control of insurance subjects.

Chapter 13.

INNOVATIONS IN ACCOUNTING REPORTING: EVALUATION OF THE READINESS OF INSURANCE COMPANIES IN MONTENEGRO³⁸⁹

Contemporary reforms in the field of accounting reporting represent one of the most significant regulatory developments in corporate governance, reflecting an effort to overcome the limitations of the traditional business model focused solely on profit maximization. This approach, dominant in previous decades, often neglected broader social, environmental and management aspects, which led to a disruption of the balance between economic growth and sustainable development. In response to these challenges, the European Union has set strong regulatory frameworks related to the integration of non-financial information in accounting reporting, which requires companies to present a more comprehensive and transparent view of their operations.

The 2014 Non-Financial Reporting Directive, followed by Directive 2022/2464/EU, established mandatory frameworks for ESG reporting, making insurance companies subject to increased regulatory obligations. However, in academic and business circles, a critical question is raised whether this regulatory framework is a true tool for improving sustainability or represents an additional administrative and financial burden for companies. A particular challenge is the harmonisation of financial and non-financial reporting, given that the financial sector, including insurance companies, traditionally operates within accounting standards aimed at quantifying financial performance, while ESG reporting requires a holistic approach, including social responsibility, environmental sustainability and corporate governance.

Because of the complexity of the application of new regulatory requirements, the European Union introduced the 'Omnibus' package of ESG regulations, with the aim of simplifying administrative procedures and increasing the competitiveness of companies. However, the question arises to what extent insurance companies, especially in Montenegro, have the capacity and willingness to integrate these newspapers into their accounting practices. Insufficiently developed institutional support, regulatory ambiguities, and limited personnel resources further

³⁸⁹ This research is part of a project CROSS-REIS – HORIZON WIDERA-2023-ACCESS-03 that has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No. 101136834.

complicate the implementation of ESG standards, while the question remains whether these reforms are strategically justified or represent a regulatory imposition without adequate systemic support.

To scientifically analyse the issue of implementing ESG innovations in accounting reporting by insurance companies in Montenegro, this chapter is conceptually structured into three analytical parts. The first segment of the research addresses the theoretical framework and review of key regulatory documents and directives that bring changes to the accounting practices of insurance companies. The second part of the research analyses the regulatory framework in Montenegro and its alignment with European standards, emphasising institutional challenges in transposing ESG regulations. The third segment empirically examines the level of readiness of insurance companies for implementing new standards, along with an analysis of the results from a survey conducted among key stakeholders in the insurance sector.

Concluding considerations provide a synthesis of findings and recommendations for improving accounting reporting in the insurance sector, with a special emphasis on optimizing the regulatory framework, strengthening institutional support and creating practical guidelines that would enable a more efficient integration of ESG factors into the business strategies of insurance companies.

The introduction of non-financial reporting into the accounting practice of insurance companies brings operational, regulatory and technical challenges that affect the integration of ESG factors into business processes and reporting. In this regard, we believe that this research provides a significant contribution to regulators, accounting policy makers and insurance companies, identifying implementation obstacles and offering guidelines to optimize the regulatory framework and facilitate compliance with ESG standards. The considerations given in the chapter contribute to the improvement of accounting policies in the insurance sector, at the same time questioning whether ESG regulation represents a strategic step forward or an additional regulatory burden.

The goal of this research is a critical evaluation of the level of readiness of insurance companies in Montenegro to implement innovations in accounting reporting, with a special focus on challenges arising from new regulatory frameworks and market requirements. The chapter will analyse the level of adaptation of existing accounting systems to new standards, the technological capacities of companies, as well as obstacles in the process of integrating ESG components into reporting practice. The results of the research will provide an insight into the current level of development of this process and enable making recommendations for the improvement of accounting policies in the insurance sector.

1. REGULATORY AND THEORETICAL ASPECTS OF THE TRANSFORMATION OF THE ACCOUNTING PRACTICE OF INSURANCE COMPANIES: ANALYSIS OF KEY DOCUMENTS AND DIRECTIVES

The issue of sustainable development is not a new phenomenon in academic and regulatory circles, but represents a concept that has been latently present since the end of the last century. However, a more intensive and systematic approach to this problem appears at the moment of the escalation of environmental challenges and global climate change, since the end of the last century. As sustainable development is considered an imperative of modern economic policies, the accounting profession did not remain immune to that process, which has led to crucial reforms in the field of corporate reporting.

Chronologically observed, a demonstrative yet key step in this reform was the adoption of the Non-Financial Reporting Directive (2014/95/EU³⁹⁰), which laid the foundation for integrating sustainability into the financial reporting of the corporate sector. However, due to identified shortcomings in the existing framework, the approach to sustainability through the lens of accounting was further enhanced and ultimately solidified at the end of 2022 with the adoption of the Corporate Sustainability Reporting Directive (CSRD³⁹¹) (hereinafter: Directive 2022/2464). This directive introduces stricter rules regarding the scope of reporting entities, establishes a unified reporting format, and lays the groundwork for a harmonised and transparent sustainable accounting practice. In addition, a highly significant innovation of the CSRD lies in the adoption of two general EU standards for sustainability reporting (ESRS – European Sustainability Reporting Standards³⁹²), while the adoption of specific sectoral standards for each ESG dimension (E, S, G) is planned.

This regulation is of particular importance in the context of improving accounting practices, as it sets clear guidelines for all financial market participants and further strengthens the principles of transparency and accountability in the reporting process.

In addition to the aforementioned directives, the framework of a sustainable financial system in the European Union has been supplemented by a series of

³⁹⁰ For more details, see: <https://eur-lex.europa.eu/eli/dir/2014/95/oj/eng> (06.04.2025)

³⁹¹ For more details, see: <https://eur-lex.europa.eu/eli/dir/2022/2464/oj/eng> (06.04.2025)

³⁹² For more details, see: https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en (06.04.2025)

regulatory acts that encourage a green transition in the financial sector. In this context, the following stand out as key: a) The EU Taxonomy for Sustainable Finance³⁹³, whose goal is to establish precise criteria for the identification of economically sustainable activities, b) The Regulation on the publication of sustainable financial information (Sustainable Finance Disclosure Regulation - SFDR³⁹⁴), which ensures the transparency of ESG factors in financial institutions, c) The European Green Deal³⁹⁵, as a broader strategic framework for the transition to a climate-neutral economy, and which is characterized as the EU's leading strategy for combating climate change³⁹⁶, d) Basel III and ESG risks³⁹⁷, which bring new approaches in risk management of financial institutions in the context of sustainability.

However, increasing regulatory and market pressures aimed at promoting sustainable finance have led to numerous challenges, including systemic abuses in the domain of ESG reporting. On a global level, there is a growing trend where companies seek to portray superior ESG performance, often with the aim of gaining a competitive advantage, attracting investors, and avoiding regulatory sanctions. This approach, however, raises concerns about the genuine commitment to the principles of sustainable business. Rather than truly integrating ESG factors into corporate strategies, companies often resort to manipulative reporting practices. One of the earliest and most prevalent phenomena in this context is *greenwashing*³⁹⁸ - a strategy of presenting a company's operations as more environmentally and socially responsible than they actually are. Such practices clearly undermine the integrity and credibility of ESG initiatives, creating an information asymmetry between companies, investors, and regulatory bodies. This calls into question the effectiveness of the entire regulatory framework, as ESG reporting, instead of serving as a tool for transparently tracking sustainability progress, becomes a means for achieving

³⁹³ For more details, see: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en and <https://energijabalkana.net/sta-je-taksonomija-odrzivih-finansija-eu/> (06.04.2025)

³⁹⁴ All relevant documents related to the promotion of sustainable finance can be found on https://mint.gov.hr/UserDocsImages/NPOO/211210_eu_taksonomija.pdf.

³⁹⁵ For more details, see: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (06.04.2025)

³⁹⁶ For more details, see: <https://rs.boell.org/sr/evropski-zeleni-dogovor> (06.04.2025)

³⁹⁷ For more details, see: <https://www.consilium.europa.eu/en/policies/basel-iii/> (06.04.2025)

³⁹⁸ In addition to greenwashing, other forms of inaccurate presentation of ESG business are also present in practice. For more details, see: <https://www.esganalytics.io/insights/social-green-blue-pink-washing> (06.04.2025)

corporate goals that are not necessarily aligned with the principles and ideals of sustainable business.

As previously emphasised, Directive (EU) 2022/2464 introduces significantly stricter regulatory requirements, which have led many companies to face challenges in adapting to the new legislative framework. This situation prompted the European Commission to propose certain amendments aimed at facilitating the transition toward more sustainable corporate operations. In response to these challenges, the Commission introduced the so-called “Omnibus” package of measures at the end of February 2025, which includes a redefinition of the timeline for implementing certain obligations and the introduction of more flexible reporting requirements, particularly tailored to small and medium-sized enterprises. These proposals aim to give companies additional time to align with the new regulatory requirements while also reducing administrative and regulatory burdens, especially for entities with limited resources. In this context, the Commission proposed a two-year postponement of the reporting obligations for companies falling under the second and third phases of Directive 2022/2464 implementation³⁹⁹.

In addition to prolonging the application of this directive, reducing the scope of companies⁴⁰⁰, the package of measures envisages a reduction in the administrative burden in order to further simplify the sustainability reporting framework. In addition, the proposal includes limiting the so-called "trickle-down" effect, which means that large companies will no longer be able to demand a disproportionate amount of data from smaller entities in their value chain. These changes aim to achieve a balance between regulatory requirements and the actual capacities of companies, ensuring sustainability and proportionality in the implementation of the new reporting standards.

As already pointed out, Directive 2022/2464 introduces stricter rules, so many companies were unprepared for the new regulatory requirements, which led the European Commission to propose certain changes in order to facilitate the transition as a sustainable corporate business. In response to these challenges, the

³⁹⁹ A proposal has been made to postpone, for two years (until 2028), the application of the reporting requirements for companies currently subject to Directive 2024/2464 and required to start reporting in 2026 or 2027. For more details, see: https://ec.europa.eu/commission/presscorner/detail/hr/ip_25_614 (06.04.2025)

⁴⁰⁰ Around 80% of companies will no longer fall within the scope of Directive 2024/2464. Only large companies will be required to report on sustainability, given their significant impact on people and the environment. For more details, see: https://ec.europa.eu/commission/presscorner/detail/hr/ip_25_614 (06.04.2025)

Commission proposed the so-called 'omnibus' package of measures⁴⁰¹, which includes adjusting the timeframe for the implementation of certain obligations and more flexible reporting requirements, especially for small and medium-sized enterprises. The proposals included in the "Omnibus" package aim to give companies more time to comply with the new requirements, but at the same time, to reduce the regulatory pressure, especially on small and medium-sized companies. In this context, the European Commission has proposed postponing the reporting obligations for companies covered by the second and third phases of Directive 2022/2464 for two years.

In addition to postponing the application of Directive 2022/2464, measures were also proposed to reduce the administrative burden on companies, in order to simplify the sustainability reporting framework. Furthermore, the proposal includes limiting the so-called "trickle-down" effect, which means that large companies can no longer demand excessive data from smaller firms in their value chain.

The Commission also proposed postponing the implementation of the Sustainability Due Diligence Directive (CSDDD) for one year. This will allow companies to gradually adapt to the new rules and reduce the risk of unnecessary administrative costs.

The intention is to make the proposed changes a more effective step towards the creation of a more efficient and flexible regulatory framework in the European Union, which balances between the ambitions of sustainable development and the needs of companies to adapt their operations to new requirements without excessive administrative burden.

In parallel with regulatory progress, examining accounting innovations through the lens of sustainable business practices, particularly in the financial sector, is a critical area of scholarly research that continues to attract significant attention from the academic community. According to the research of Marti, Bastida-Vialcanet and Marimon (2024), the number of scientific works dedicated to this topic has grown significantly in the last decade, which indicates an increasing need to develop systemic solutions that enable the integration of sustainability into corporate strategies and regulatory frameworks, while the analysis of the number of published scientific articles in the period from 2000 to 2022 shows a gradual increase in interest in this area, with a sharp increase in the number of

⁴⁰¹ For more details, see: https://ec.europa.eu/commission/presscorner/detail/hr/ip_25_614 (06.04.2025)

publications after 2019, which suggests an expansion of research conditioned by growing global attention to relevant topics and regulatory reforms.

Namely, studies addressing the integration of ESG criteria in the insurance sector lead to the conclusion that the ESG concept is increasingly becoming an integral part of business strategy. Johannsdottir and McInerney (2018) propose a framework for its application; Nogueira et al. (2018) develop a model for managing ESG issues; Gharizadeh-Beiragh et al. (2020) analyse its implementation in insurance companies; while Thomae et al. (2021) examine its impact on pension funds. A common conclusion among these authors is that ESG is not viewed solely as a regulatory burden, but rather as a significant criterion for achieving better market positioning and sustainability. Their findings align with those of Zhou, Liu, and Luo (2022), who investigate the relationship between sustainable development, financial performance, and the market value of insurance companies, as well as Brogi et al. (2022), who empirically examine the correlation between ESG ratings and the financial performance of 107 large insurance firms in the United States, concluding that ESG may have a positive impact on long-term profitability.

ESG criteria and risk management in insurance—particularly in the context of climate change—are crucial for the sector's long-term stability. This is confirmed by the findings of Mills (2009), who explored whether the development of insurance products could contribute to mitigating climate-related risks. Closely related to this, Braun et al. (2019) addressed the issue of exposure to carbon-intensive investments, while Robineau (2019) examined the integration of climate change considerations into risk assessment models.

In support of the fact that insurance companies are increasingly integrating ESG principles into their operations, research by Alshadadi, Deshmukh and Zaid (2024) also testifies, the study emphasises that ESG is no longer just a regulatory requirement, but becomes a strategic imperative that shapes the long-term stability, reputation and competitive advantage of insurers, while through innovations in insurance products and the digitisation of ESG reporting, a sustainable transformation of the sector is ensured.

These findings are consistent with the results of studies conducted in 2022⁴⁰² and 2023⁴⁰³. Namely, studies suggest that ESG is becoming a fundamental strategic

⁴⁰² For more details, see: <https://www.pwc.com/us/en/industries/insurance/library/assets/pwc-next-in-insurance-esg.pdf> (10.04.2025)

⁴⁰³ For more details, see: <https://assets.kpmg.com/content/dam/kpmgsites/xx/pdf/2024/02/esg-in-insurance-report.pdf> (10.04.2025)

imperative for insurance companies, with 85% of global insurers believing that sustainability will have a significant impact on all business functions, while the greatest effects are expected in investment strategies (91%), risk management (90%) and insurance risk assessment (88%). The environmental dimension of ESG is becoming increasingly important, as 51% of insurers have already undertaken or are planning to undertake commitments related to achieving net-zero emissions, while digitisation and automation of ESG reporting are necessary tools for regulatory compliance and optimisation of reporting processes.

The social component of ESG poses additional challenges, as 69% of insurance CEOs express concern about the impact of social inequality on attracting and retaining highly skilled staff, while the global insurance protection gap continues to widen and is projected to reach \$1.86 trillion by 2025. Corporate governance of ESG policies is still underdeveloped, with less than 50% of companies listed on the London Stock Exchange (FTSE 100) linking executive compensation to ESG goals, while the European Insurance and Occupational Pensions Authority (EIOPA) is intensifying regulatory oversight to prevent greenwashing practices and ensure the credibility of non-financial reporting in the insurance sector.

Furthermore, the research conducted in 2023⁴⁰⁴ among insurance companies in the CEET region indicates that they are in the early stages of ESG integration, with the regulatory and supervisory frameworks being insufficiently developed and significantly varying between EU members and non-members. The general opinion is that the existence of limited regulatory capacities and the lack of ESG data represent the main obstacles, which certainly require stronger institutional support. Namely, the research indicates that 43% of regulatory bodies have defined ESG risks, while 86% of supervisory bodies report a lack of professional capacity to implement ESG standards. ESG factors are most often integrated through risk management (44%), ESG disclosure (35%) and investment policies (26%), while key challenges include a lack of quality data (82%) and regulatory fragmentation. In Serbia and Montenegro, ESG implementation depends on EU harmonisation, with the study stating that Montenegro is progressing through the negotiation chapters, while Serbia still does not have a national strategy for ESG in insurance.

⁴⁰⁴ For more details, see: https://a2ii.org/sites/default/files/2024-09/a2ii_azn_report_on_sustainability_esg_regulatory_landscape_in_ceet.pdf (10.04.2025)

2. INNOVATIONS IN THE REGULATORY FRAMEWORK: REVIEW OF LEGAL SOLUTIONS IN MONTENEGRO

In the context of current regulatory reforms and strategic transition towards sustainable business, it can be stated that Montenegro is formally making progress in ESG integration, which is also confirmed by the fact that, in order to fulfill the requirements of Chapter 6 - Commercial Law and Chapter 32 - Financial Supervision, it has intensified regulatory reforms in the area of non-financial reporting and ESG standardization. Back in 2014, Montenegro began the process of harmonizing its legislation with Directive 2013/34/EU and Directive 2014/95/EU, which resulted in the differentiation of the Law on Accounting and the Law on Auditing, and in accordance with the Law on Accounting from 2016, non-financial reporting was regulated through one article that transposed the provisions of Directive 2014/95/EU. However, empirical data indicate that the implementation of this regulatory framework was limited and ineffective, since those obliged to report showed a low degree of compliance with the new regulatory requirements.

Research conducted through interviews with relevant institutions and companies showed that business entities were either not familiar with the obligation of non-financial reporting or did not apply it systematically. Although amendments to the Accounting Act from 2021 formalised additional obligations in the field of ESG reporting, their application in practice remained fragmented. With the growing importance of sustainable business on a global level, as well as the fact that the financial sector in Montenegro is characterised by a high level of presence of foreign capital, ESG factors become a strategic imperative for domestic financial institutions. In this context, some banks and insurance companies have started the institutionalisation of ESG policies by establishing special sectors and expert teams dedicated to the analysis and application of sustainable standards. However, the key challenge remains the development of regulatory capacities and personnel education, in order to ensure adequate application of ESG principles in accordance with international guidelines and regulatory requirements.

Currently, Montenegro is entering a critical phase of ESG regulation, given that the Draft Law on Accounting for 2025 seeks to integrate the provisions of Directive (EU) 2022/2464. Although the primary goal of this regulatory framework is to increase transparency and harmonise non-financial reporting with European standards, preliminary analyses indicate that the proposed legal framework is characterised by a high degree of administrative complexity, which may result in significant financial and operational costs for economic entities. A special challenge is the obligation of ESG reporting in accordance with the new

European standards, which requires significant resources for the development of internal reporting systems, which can be extremely burdensome for small and medium-sized companies. Although the legislator strives for the full integration of ESG principles in financial and non-financial reporting, it is necessary to adopt a pragmatic approach, which will enable gradual adjustment of the economy, instead of imposing rigid regulatory frameworks that can slow down economic dynamics.

In this regard, the recently proposed solution through the Omnibus package of measures is also justified, which envisages the phased implementation of ESG obligations, whereby companies would be enabled to progressively switch to a new reporting system, while minimizing administrative and financial burdens. Also, this approach enables regulatory institutions to gradually introduce ESG requirements through an adaptive supervisory framework, taking into account market capacities and the specificities of the national economy.

For insurance companies in Montenegro, these regulatory changes will have substantial repercussions on business models, risk management strategies and investment policies. ESG requirements will significantly influence underwriting policies, which will have to be aligned with the principles of sustainable financing and climate risk management. Also, the introduction of mandatory ESG reports will create a need for the development of new sustainability assessment methodologies, as well as intensive investment in the professional education of employees in the insurance sector. Although the application of new ESG regulations will initially represent a challenge and a financial burden, in the long term, it can strengthen the credibility and competitiveness of insurers on the regional and international markets, especially in the context of the increasingly strict requirements of European legislation. Insurance companies, through the adequate implementation of ESG standards, will be able to play a key role in the development of sustainable financing and the promotion of green investments, thereby contributing to the stability of the financial sector and the long-term economic sustainability of Montenegro.

3. METHODOLOGY AND RESULTS OF ANALYSIS

To get more insights into the ESG challenges in accounting practices of insurance companies, a qualitative survey was conducted with representatives of seven insurance companies operating in Montenegro. The research focused on the implementation of innovations in accounting practices through the ESG lens. The objective was to assess the current state of ESG integration, identify key challenges, and formulate recommendations for improvement.

The research was carried out during March and April 2025 in the form of structured interviews with representatives from seven different insurance companies active on the Montenegrin market. The questionnaire was semi-structured, combining closed-ended questions with rating scales and open-ended questions that allowed participants to elaborate on their responses and express their views.

The survey was administered via an online form, which enabled greater flexibility and ease of data processing. The collected responses were analyzed using descriptive and qualitative methods, aiming to identify recurring patterns in the attitudes, experiences, and perceptions of the respondents. This mixed-methods approach provided a deeper understanding of the complexity of ESG integration in the accounting practices of insurance companies.

The sample included companies of varying sizes, ownership structures, and levels of digitalization, allowing for a broader view of the sector and diverse perspectives. Although the sample size was limited, it was indicative as it included leading market participants in the Montenegrin insurance sector.

Results of the Interview analysis

The following empirical analysis presents the key insights drawn from the survey responses. It is structured around four main thematic areas that emerged from the questionnaire: (1) current ESG practices, (2) the state of digitalization in accounting, (3) training and capacity-building efforts, and (4) the challenges associated with ESG implementation. This structure allows for a comprehensive and nuanced understanding of the readiness, obstacles, and perspectives within the insurance sector in Montenegro regarding ESG integration. Each section contextualises the responses and explores recurring patterns and attitudes among participants, offering a foundation for evidence-based recommendations.

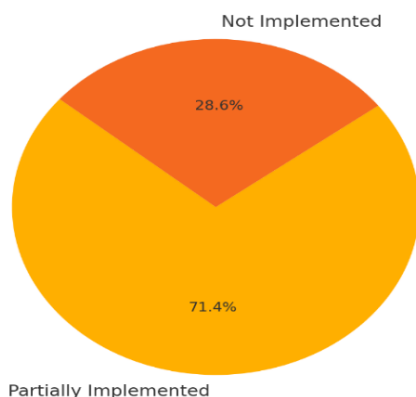
The interviews were conducted with individuals holding key positions within the companies, including accountants, chief financial officers, and heads of finance and accounting departments. Most respondents have over eight years of professional experience in the accounting sector of their respective companies. Additionally, based on annual revenue, the surveyed companies fall into the category of large enterprises. In terms of ownership structure, the majority are either partially or fully owned by international corporations. Regarding the level of digitalisation, the respondents assessed their companies as having well-digitalised accounting processes.

Given these characteristics—experienced professionals, large company size, international corporate structures, and advanced digitalization—the surveyed companies demonstrate a solid foundation for addressing and implementing ESG standards within their accounting practices.

Current ESG Practices in Insurance Companies

The questions related to ESG implementation aimed to examine to what extent insurance companies in Montenegro incorporate environmental, social, and governance aspects into their accounting practices. This area is crucial because ESG standards form the basis for responsible business practices that are increasingly recognised and demanded by investors, partners, and regulators.

Figure 1. Implementation status of ESG standards

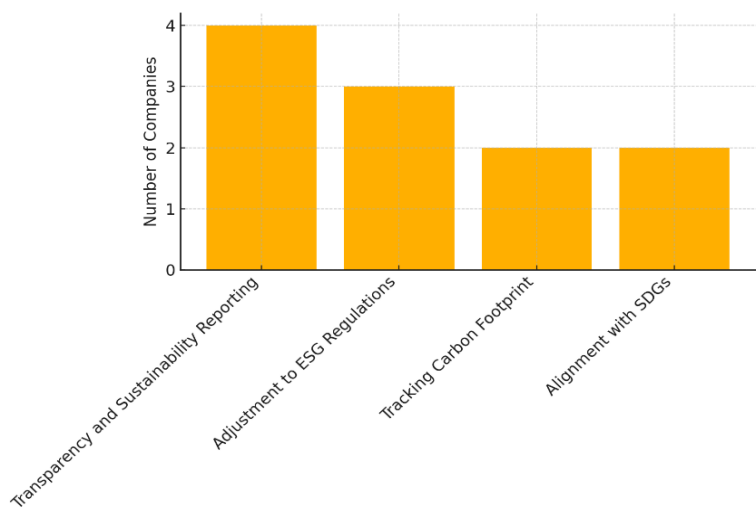


Source: Authors' calculation

The results show that most companies (5 out of 7) currently apply ESG standards only partially. The remaining two companies do not yet apply these standards but are in the planning and consideration phase. Partial implementation often means that certain ESG elements are present in reports or internal procedures but without a systematic approach. Similarly, five companies stated they occasionally prepare a sustainability report, suggesting awareness of the importance of non-financial reporting, although not on a regular or integrated basis.

In terms of regulatory compliance, four respondents believe their companies are partially aligned with ESG requirements, two claim to be fully compliant, and one is unsure of their compliance level. These findings indicate a potential lack of clarity or understanding regarding applicable regulations.

Figure 2. Integration of ESG factors into the accounting process



Source: Authors' calculation

Regarding the integration of ESG factors into accounting processes, the survey revealed the following key insights: (1) Transparency and Sustainability Reporting were the most frequently cited factors, mentioned by 4 out of 7 respondents. This suggests that companies are primarily focusing on enhancing the openness and accountability of their financial disclosures, aligning them with broader sustainability goals. (2) Adjustment of Financial Reports to ESG Regulations was identified by 3 respondents. This indicates that companies are increasingly adapting their financial reporting frameworks to incorporate ESG-related regulatory requirements. (3) Tracking Carbon Footprint through Financial Reports was noted by two respondents, reflecting an emerging trend where environmental impact metrics are becoming part of the financial reporting process. (4) Alignment of Accounting Practices with Sustainable Development Goals (SDGs) was also cited by two respondents, demonstrating that certain companies are consciously linking their accounting activities with global sustainability targets.

Overall, these responses demonstrate that while some ESG elements have been integrated into accounting processes, the focus remains primarily on transparency and compliance. The integration of more complex environmental and social metrics into accounting frameworks is still in its early stages but shows promising signs of development.

Digitalisation of Accounting Processes

Digitalisation is a key component of modern accounting, especially in the context of ESG, which requires handling large volumes of data and the need for transparency and real-time performance tracking. Questions in this segment aimed to determine the technological readiness of companies to integrate ESG reporting into daily operations.

Responses revealed a heterogeneous level of digital capacity. Some companies are fully digitalised, using advanced software tools, while others are just beginning the process of automation and digital transformation. This suggests significant disparities in technical readiness and highlights the need for support for companies lagging in this area.

Respondents recognised the benefits of digitalisation, particularly in relation to ESG, but also pointed to barriers such as high costs, lack of integrated software solutions, and the need for additional employee training.

Training and Capacity Development

Human capital and its knowledge of ESG principles play a crucial role in the successful implementation of sustainable accounting. Questions about training were designed to assess current activities related to strengthening the ESG competencies of employees.

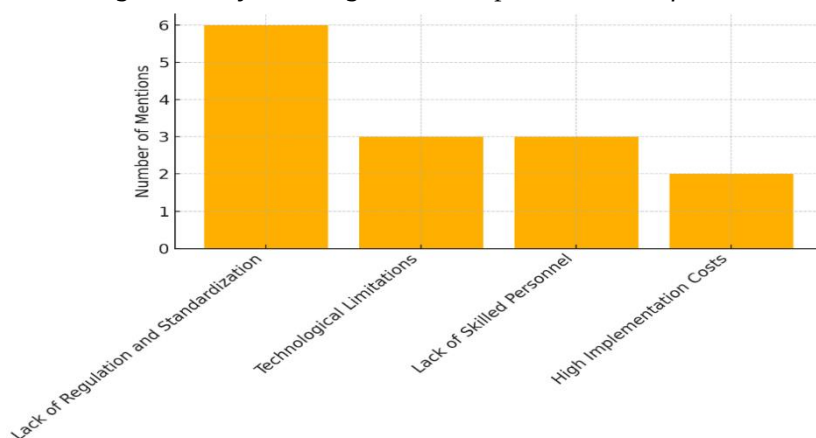
Most companies do not organise regular ESG training—four plan to introduce it in the future, one offers occasional training, and only one has a consistent training program. However, all respondents agreed that ESG training would be beneficial, at least for specific departments within their organisations. This consensus highlights the need for a structured approach to skills development, alongside the current lack of available education.

Respondents expressed a readiness to improve knowledge in this field, though progress remains dependent on the availability of specialised programs, institutional support, and management engagement.

Key Challenges in Implementing ESG Innovations

Identifying challenges is a core part of this research, as it provides a deeper understanding of the obstacles companies face in integrating ESG standards into their accounting practices. These open-ended questions allowed respondents to share specific experiences and insights.

Figure 3. Key challenges in the implementation of ESG



Source: Authors' calculation

The most frequently cited challenge was the lack of regulation and standardization, mentioned by nearly all respondents (6 out of 7). This indicates the absence of a well-defined institutional framework and clear guidelines. Other recurring issues include technological limitations, lack of qualified personnel, and high costs associated with implementing ESG tools and reporting frameworks. Participants viewed these challenges not only as technical but also strategic, requiring support at the highest institutional levels—from policymakers and regulators to sectoral associations.

Views on the Future of ESG in Financial Reporting

The final segment explored how companies perceive the future of ESG innovations in financial reporting. A positive outlook would indicate readiness for long-term transformation, while skepticism would reflect the need for greater awareness and support.

Most respondents (5 out of 7) expressed uncertainty, while one was explicitly sceptical, stating that ESG innovations are not the future of financial reporting. These perceptions highlight a relatively low level of confidence in the long-term relevance of ESG requirements and signal the need for better education about global regulatory trends, including the EU Taxonomy, CSRD, and other initiatives that are positioning ESG as an integral part of corporate reporting.

Based on the findings, it can be concluded that the insurance sector in Montenegro demonstrates an initial, but still underdeveloped, capacity to integrate ESG principles into accounting practices. Signs of progress are evident, yet a systemic approach is needed, including regulatory support, financial

incentives, and capacity-building initiatives that will raise awareness of all stakeholders. According to these findings, the main recommendations would be:

- Policymakers should develop clear ESG guidelines and standards.
- Introduce subsidies for digitalisation and ESG training.
- Develop specialised programs and certifications for ESG accounting.
- Support best practice sharing and regional cooperation within the insurance sector.

These findings would serve as a starting point for further research and targeted actions aimed at strengthening the role of sustainability in the accounting functions of insurance companies in Montenegro.

Summary of research results

Insurance companies are under increasingly strong regulatory pressures and expectations regarding ESG reporting. The growth of normative obligations at the global level requires not only technical and organisational adaptability but also a strategic reconceptualisation of reporting models.

The conducted research indicates that insurance companies in Montenegro have basic capacities for the integration of ESG standards, including professional staff, digitised accounting processes and corporate structures, but their application of ESG principles remains partial and insufficiently institutionalised. The lack of a systematic approach, limited compliance with regulatory requirements and fragmented non-financial reporting practices suggest the need for additional regulatory guidance, education and strategies that would enable more effective integration of ESG factors into accounting functions.

The results of the research also indicate significant differences in the degree of digitisation of insurance companies, whereby the technical readiness for the integration of ESG principles varies, which also points to the need for additional infrastructural and educational support. The lack of standardised regulations, limited human capacities and high costs represent key obstacles to the successful implementation of ESG standards, and emphasise the importance of strategic and institutional intervention in the process of transition to sustainable accounting.

Respondents' views on the future of ESG innovations in financial reporting indicate a limited level of trust and understanding of the long-term importance of ESG principles. These findings confirm that the insurance sector in Montenegro has initial capacities for ESG integration, but that a systemic and strategic intervention is necessary for essential transformation.

INVESTMENT ACTIVITY OF INSURANCE COMPANIES: BETWEEN REGULATORY CONSTRAINTS AND MARKET REALITY

To effectively fulfil their primary function of providing economic protection against risks, insurance companies act as institutional investors that channel long-term funds into the economy. They transform a large number of small, periodic premium payments into substantial financial reserves. Due to the time lag between premium inflows and benefit outflows, the funds thus accumulated can be invested until claims fall due. Through this process, insurance companies contribute to the mobilisation of savings and the financing of public and private sector investment, supporting economic development. Their conservative investment approach, combined with the long-term nature of their liabilities, enables them to serve as stabilisers of financial markets, especially during periods of economic distress.⁴⁰⁵ Unlike most financial market participants, insurers, especially those engaged in life insurance, are less likely to engage in pro-cyclical behaviour, such as panic-selling during market downturns.⁴⁰⁶ Importantly, the funds managed by insurance companies ultimately belong to policyholders and must be invested in a way that ensures safety, liquidity, and the ability to meet future obligations as they come due. For this reason, the regulation of insurers' investment activity is one of the most important pillars of insurance supervision.

While investment regulation aims to ensure that insurers invest prudently and are able to meet their obligations to policyholders, regulatory approaches vary considerably. The Solvency II framework, implemented across the European Union, is based on the prudential principle, granting insurers greater flexibility in investment portfolio management while requiring robust internal risk assessment and capital adequacy. However, the effectiveness of this model is closely linked to the depth and liquidity of the financial market and the institutional maturity of both insurers and regulators.

⁴⁰⁵ Kočović, J., Rakonjac-Antić, T., Koprivica, M., & Šulejić, P. (2021). *Osiguranje u teoriji i praksi*. Belgrade: University of Belgrade, Faculty of Economics and Business, p. 364.

⁴⁰⁶ Schich, S. (2009). Insurance Companies and the Financial Crisis. *OECD Journal: Financial Market Trends*, 2, p. 17.

In contrast, countries with underdeveloped financial markets, such as Serbia, face structural limitations that constrain the practical applicability of the prudential approach. In such environments, regulators typically rely on quantitative limits as a substitute for market discipline and as a safeguard against excessive risk exposure. This raises an important question: to what extent can the regulatory philosophy behind Solvency II be realistically applied in countries with limited investment opportunities and narrow capital markets?

The subject of this chapter is the investment activity of insurance companies, with a focus on the interaction between regulatory constraints and market conditions. The main objective is to analyse how different regulatory approaches — prudential and rule-based — shape the investment behaviour of insurers, and to what extent market underdevelopment, particularly in Serbia, imposes additional constraints beyond those prescribed by regulation.

1. INVESTMENT RISKS FACED BY INSURANCE COMPANIES

As institutional investors, insurers are exposed to a broad spectrum of investment risks that affect both portfolio performance and their ability to meet policyholder obligations. Understanding and effectively managing these risks is essential not only for protecting the solvency of individual insurers but also for maintaining trust in the insurance sector as a whole. This section provides an overview of the key investment risks insurance companies face, including market, credit, concentration, and liquidity risks.

Market risks arise from the sensitivity of asset values to fluctuations in financial variables such as interest rates, exchange rates, equity prices, and the prices of underlying instruments in derivative contracts. The key components of market risk include:

- *Asset depreciation risk* – the risk of a decline in the market value of investment assets due to adverse market movements. Insurers are especially exposed to this risk through their investments in equities and real estate, whose prices can be particularly sensitive to macroeconomic conditions and market volatility.
- *Interest rate risk* – refers to the potential for financial losses arising from fluctuations in interest rates. Insurers are particularly sensitive to this risk due to their significant exposure to long-term fixed-income securities, especially government bonds. Although such bonds offer stable and predictable income streams, their market value declines when interest rates rise, as new bonds offer higher returns. The resulting capital losses may weaken the company's solvency and its ability to meet future claims.

- *Spread risk* – the risk of a decline in the market value of fixed-income securities due to widening credit spreads. It occurs when the yield gap between a corporate bond and a risk-free benchmark (e.g. government bond) increases, often due to deteriorating credit quality or market sentiment. This can cause significant capital losses for insurers heavily exposed to corporate debt.
- *Foreign exchange risk* – the risk of a decline in the value of investment assets denominated in foreign currencies due to fluctuations in exchange rates. Insurers may be exposed to this risk when they invest in foreign securities or hold assets and liabilities in different currencies.
- *Risks associated with the use of derivatives* – insurers that use derivatives face risks associated with the timing and ability to execute contracts (liquidity risk), unexpected price behaviour of the underlying assets (basis risk), and operational risks related to inadequate internal systems, procedures and controls. While derivatives can be used to hedge market risk, they may also amplify exposure if not properly managed.

Credit risk refers to the potential for financial loss arising from the inability or unwillingness of an issuer of financial instruments held in the insurer's investment portfolio to meet its contractual obligations in full and on time. Insurers are particularly exposed to credit risk through their investments in corporate bonds, structured finance instruments, and bank deposits. The exposure level depends on the issuer's credit rating, the asset's maturity structure, the degree of investment concentration,⁴⁰⁷ and macroeconomic conditions.

Concentration risk refers to the potential for financial losses arising from an overexposure to a single asset, issuer, sector, or geographical region. Excessive concentration undermines the benefits of portfolio diversification and can significantly amplify the impact of adverse events, such as credit deterioration or sector-specific economic shocks. Regulators may impose quantitative limits on exposures to individual counterparties or asset classes to mitigate this risk and ensure a more resilient investment portfolio structure.

Liquidity risk refers to the potential loss arising from the inability to meet current liabilities due to insufficient liquid assets. This risk materialises when an insurer is forced to borrow or sell assets under unfavourable market conditions. A common cause of liquidity shortfall is the misalignment of asset and liability maturities, when short-term liabilities are financed through long-term, illiquid

⁴⁰⁷ Jovović, M. (2015). *Merenje rizika pri utvrđivanju solventnosti neživotnih osiguravača. Doctoral dissertation*, Belgrade: University of Belgrade, Faculty of Economics and Business, p. 25.

investments. Non-life insurers are especially exposed to this risk because their liabilities and funding are mostly short-term.⁴⁰⁸

The investment risks outlined above may lead to losses in specific asset classes or reduce expected returns, ultimately undermining the insurer's capacity to meet obligations toward policyholders. For this reason, investment activity must remain subordinate to the insurer's primary function of providing financial protection. To avoid compromising solvency, investment decisions must prioritise policyholder interests and ensure sound alignment of assets and liabilities, particularly regarding maturities, currencies, and interest rate exposure. Special attention must be given to the continuous coverage of technical reserves by high-quality and appropriately structured assets.

2. FACTORS SHAPING INSURERS' INVESTMENT PORTFOLIO STRUCTURE

The main investment types for insurance companies include real estate, securities, and deposits with banks and other financial institutions.⁴⁰⁹ The structure of an insurer's investment portfolio is shaped by a combination of general and country-specific factors. Among the general factors that apply across different countries are the security objective inherent in insurance activity and the type of insurance in which a given company is engaged.⁴¹⁰ These factors stem from the nature of the insurance business and influence investment decisions regardless of regulatory or market context.

The investment policy of insurance companies is based on three core principles: security, profitability, and liquidity, similar to those of other institutional investors. However, because the primary function of insurance is to provide financial protection against risk, security takes precedence over other investment principles. Due to this prioritisation, insurers tend to structure their portfolios around low-risk or relatively safe assets. As a result, technical reserves are, in

⁴⁰⁸ Jovović, M., Mitrašević, M., & Kočović, M. (2013). Assessment of financial strength of insurance companies in Serbia. In: *Product specifics on the markets of insurance and reinsurance*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, p. 340.

⁴⁰⁹ Kočović et al. (2021), op. cit., p. 369.

⁴¹⁰ Kočović, J., Paunović, B., & Jovović, M. (2015). Possibilities of creating optimal investment portfolio of insurance companies in Serbia. *Ekonomika preduzeća*, 7-8, p. 387.

general, predominantly invested in government bonds, long-term bonds issued by state-owned enterprises, and bank deposits.⁴¹¹

The structure of insurers' investments is also determined by the nature of their liabilities, particularly in terms of predictability and duration.⁴¹² Life and non-life insurers differ significantly in this regard.⁴¹³ In life insurance, the timing and amount of future obligations are more predictable, as benefits are contractually fixed. Liabilities are long-term in nature because contracts are generally long-term. In contrast, non-life insurance claims are uncertain in both timing and amount. Liabilities are short-term in nature because contracts are typically short-term. Accordingly, life insurers allocate a larger portion of their portfolios to long-term, less liquid assets, while non-life insurers tend to favour short-term, highly liquid investments.⁴¹⁴

However, in practice, two additional factors play a critical role in shaping insurers' investment portfolios: the regulatory framework and the level of development of the domestic financial market. These factors are highly context-dependent and can vary significantly across countries.

Regulatory framework as a determinant of insurers' investment structure

Investment regulation, particularly with respect to the allocation of technical reserves, is essential for ensuring that insurers hold sufficient and appropriate assets to meet their obligations to policyholders.⁴¹⁵ Two main regulatory approaches can be distinguished: the principles-based "prudent person rule" and the rules-based "quantitative portfolio regulations." Table 1 provides a comparative overview of two methods, highlighting respective advantages and limitations.

⁴¹¹ Kočović, J., Rakonjac Antić, T., & Jovović, M. (2011). The impact of the global financial crisis on the structure of investment portfolios of insurance companies. *Economic Annals*, LVI(191), p. 145.

⁴¹² Davis, P. (2000). Portfolio regulation of life insurance companies and pension funds. *Pension Institute Working Paper*, PI-0101, p. 4.

⁴¹³ López Domínguez, I. (2023). Insurance companies in the European Union: General criteria affecting investment policies. *Journal of Governance and Regulation*, 12(2), 77-p. 81.

⁴¹⁴ Kočović et al. (2015), op. cit., p. 388.

⁴¹⁵ Davis, P. (2002). Prudent person rules or quantitative restrictions? The regulation of long-term institutional investors' portfolios. *Journal of Pensions Economics & Finance*, 1, p. 165.

Table 1. Comparison of regulatory approaches to insurance investments

Criterion	Prudent person rule	Quantitative portfolio regulations
Flexibility	High: Insurers have broad discretion if investments are justified as prudent.	Low: Rigid investment caps limit decision-making.
Risk sensitivity	High: Investment strategies can be aligned with each insurer's risk profile and liabilities.	Low: Rules ignore actual risk exposures or correlations.
Risk-return optimisation	High: Enables diversification and more efficient portfolios.	Low: Limits can lead to suboptimal portfolios.
Contribution to financial market development	High: Encourages innovation and demand for a wider range of financial instruments.	Low: Restrictive rules may limit market depth and innovation.
Clarity and simplicity	Lower: Requires judgment and case-by-case review.	High: Clear rules enable easy compliance checks.
Supervisory burden	High: Requires skilled supervision and detailed oversight.	Low: Compliance is mostly checked through standard reporting.
Compatibility with solvency regime	Aligned with risk-based regimes (e.g. Solvency II)	Used in rules-based regimes (e.g. Solvency I)
Market suitability	Suitable for developed markets with mature financial systems, robust governance, and skilled supervisory authorities.	More appropriate for emerging markets with less developed financial systems, evolving governance structures, and limited supervisory capacity.

Source: Authors' own compilation

The prudent person rule is a qualitative standard that requires insurers to manage their investments as a “prudent” investor would, considering the nature and duration of liabilities, overall risk exposure, and the interests of policyholders. It does not prescribe fixed limits for specific asset classes; instead, insurers are free to invest in any asset as long as they can justify the investment as prudent in the context of their liabilities and risk management. This approach grants insurers considerable flexibility in managing their investment portfolios. It allows for a broader range of asset classes, including infrastructure loans, private equity and other alternative assets, which may be excluded under strict quantitative rules. Without rigid, uniform limits, investment decisions can be tailored to each insurer's risk profile and liability characteristics. This flexibility enables insurers to pursue optimal investment strategies and adapt to changing market conditions.

By focusing on overall portfolio risk, the prudent person approach aligns with modern portfolio theory.⁴¹⁶ Through broad diversification, this approach enables the construction of an efficient portfolio that optimises the risk-return trade-off.

The principle-based nature of the prudent person rule allows it to remain relevant as financial markets evolve. Insurers can invest in new asset classes (e.g. green bonds) without waiting for formal rule changes, enabling more agile responses to economic shifts. From a macroeconomic perspective, this adaptability also supports financial innovation by reducing regulatory delays.

Moreover, the prudent person rule aligns naturally with risk-based supervision frameworks like Solvency II. Since risky investments already carry higher capital requirements, the prudent person approach complements this by reinforcing governance and portfolio oversight without prescribing arbitrary limits. It shifts regulatory focus toward outcomes and risk management processes rather than compliance with predefined thresholds.

Despite its merits, the prudent person rule also presents important challenges. One of them is the high reliance on the insurer's expertise and supervisory capacity. The effectiveness of the approach depends heavily on the ability of insurers to develop robust risk management systems and on the competence of supervisors to evaluate complex investment strategies.

If an insurer lacks adequately skilled investment professionals or strong internal risk controls, the application of the prudent person rule alone may not be sufficient to prevent suboptimal or even harmful investment decisions. In less sophisticated markets or companies, this could lead to excessive risk-taking or misjudgments. An insurer might be tempted to "reach for yield" or take on excessive investment risk to boost profits, thinking it can justify it as prudent. Without hard limits, there is a possibility that discipline erodes, especially if there is competitive pressure to deliver returns. Expertise, strong governance and ethical standards are needed; otherwise, policyholders could be exposed to unintended risks. Thus, prudent-person regimes must be buttressed by a strong risk culture and vigilant supervision to prevent misconduct or moral hazard.

The implementation of the prudent person rule imposes a significant supervisory burden. Ensuring compliance requires detailed assessments of insurers' investment processes and risk management practices, which can demand substantial time and resources. Supervisors may have to impose remedies like

⁴¹⁶ Weigl, C. S. (2013). Prudent Investor Rule and Modern Portfolio Theory. *Estates, Trusts & Pensions Journal*, 33, p. 145.

capital add-ons or investment restrictions on a case-by-case basis if they find imprudent practices. This tailored oversight is effective but costly.

Finally, the effective implementation of the prudent person rule presupposes the existence of a well-developed financial market. A broad range of investment options is essential for insurers to fully benefit from the flexibility this approach provides. In shallow and illiquid financial markets, insurers may be forced to concentrate their portfolios in a narrow set of available assets or face additional risks due to limited diversification. Thus, while the prudent person rule is well-suited to developed insurance markets, its advantages may be significantly reduced in emerging markets where governance standards, supervisory capacity, and financial market infrastructure are still evolving.

By contrast, quantitative portfolio regulations impose explicit limits on investments. Laws or regulations define how much an insurer can invest in specific asset classes or exposures, including issuers, sectors, or regions. Limits are commonly placed on holdings of assets with relatively volatile prices, low liquidity, or high credit risk.⁴¹⁷ This approach has been used in factor-based solvency regimes (such as Solvency I in Europe). It is still commonly used in some developing economies, where regulators mandate, for instance, a high proportion of assets to be in government bonds or bank deposits, and impose strict caps on riskier asset classes like equities or overseas investments.

One of the most notable advantages of this approach is its clarity and simplicity. Numeric thresholds offer a clear compliance framework, enabling insurers to structure portfolios easily and supervisors to detect breaches through routine reporting. This is particularly beneficial in emerging markets, where supervisory capacity may be constrained.

By capping exposures to higher-risk asset classes or single issuers, the rules automatically restrict extreme risk-taking behaviour. In markets where risk-based capital models are not fully operational, these limits function as a blunt but effective safeguard, particularly in preventing concentrations or speculative investments that could threaten solvency. Quantitative regulations can also serve broader policy objectives, such as encouraging domestic investment or limiting foreign exchange exposure, thereby supporting macroeconomic stability.

This regime promotes uniform minimum standards of prudence across the industry. Quantitative rules apply equally to all insurers. Such uniformity prevents a “race to the bottom” where some insurers might otherwise take on more risk to outcompete others. It also enhances public trust through consistent

⁴¹⁷ Davis (2000), *op. cit.*, p. 24.

conservative investment behaviour across the industry. In volatile markets with weak market discipline, strict asset limits help preserve solvency. More precisely, having insurers primarily invested in domestic government bonds might reduce the chance of investment-driven failures.

However, quantitative portfolio regulations also have significant limitations. Their rigidity may prevent insurers from fully optimising investment portfolios. By focusing on the risk of individual assets, they overlook the potential for overall portfolio risk reduction through diversification. This can result in suboptimal performance, as insurers might be forced into lower-yield or less diversified portfolios. Numerous empirical studies show that explicit limits constrain investment efficiency, thereby imposing opportunity costs on insurers (and ultimately on policyholders) in terms of risk-adjusted returns.⁴¹⁸

Due to their uniform nature, quantitative rules are not risk-sensitive. They apply equally to all insurers, regardless of their risk profile or liability structure. Moreover, limits are usually arbitrarily calibrated, i.e. based not on rigorous risk assessments, but on overly cautious heuristics. This approach may be suboptimal for well-capitalised insurers who could take on more risk to improve returns or asset-liability matching. Also, these rules treat all assets in a category the same and fail to account for correlations between different types of assets. As such, they may create a false sense of security: an insurer may meet all regulatory limits while still holding a portfolio that is mismatched or concentrated in hidden ways.

The static nature of quantitative rules also limits adaptability to evolving financial markets. Insurers may be unable to invest in new financial instruments until regulations are formally updated. Similarly, a limit imposed several years ago may now be too conservative, yet changing laws or regulations is often slow. Consequently, insurers may remain constrained by outdated allocation rules that no longer reflect current investment opportunities or macroeconomic conditions.

Finally, excessive reliance on quantitative rules may hinder the development of insurers' internal risk management and the broader financial market. Strict regulatory limits can shift focus from governance and expertise to mere

⁴¹⁸ See more in Jones, L. D. (1968). *Investment Policies of Life Insurance Companies*. Boston: Division of Research, Graduate School of Business Administration, Harvard University; Davis (2000), op. cit.; Bijapur, M., Croci, M., & Zaidi, R. (2012). *Do asset regulations impede portfolio diversification? Evidence from European life insurance funds*. New York: Social Science Electronic Publishing; Kočović et al. (2015), op. cit.

compliance.⁴¹⁹ In the longer term, this can discourage the growth of a strong risk culture within the industry. From a macroeconomic perspective, if large institutional investors like insurers are restricted to government bonds, demand for other financial instruments may stagnate. This may limit the development of local capital markets and reduce insurers' contribution to long-term economic growth. Therefore, it is recommended that such restrictions be eased once appropriate risk-based supervision is in place, provided that this does not harm the interests of policyholders.⁴²⁰

These regulatory approaches directly influence the structure of insurers' investment portfolios, determining the range of permissible assets and the degree of flexibility in portfolio construction. As the analysis shows, each approach has distinct advantages and limitations. The choice between them largely depends on the level of market development. Broadly, developed markets have trended toward the prudent-person principle, while emerging markets more often rely on quantitative limits as the dominant form of investment regulation.

Impact of financial market development on insurers' investment opportunities

The level of financial market development in a country is another critical determinant of insurance companies' investment portfolio structure. In addition to regulation, the depth and breadth of the local capital market fundamentally shape insurers' investment opportunities and influence their ability to perform effective asset-liability management.

In well-developed financial markets (typically found in advanced economies), insurers can pursue more diversified and long-term investment strategies. A deep capital market provides access to various asset classes, from government and corporate bonds to equities, private debt, and alternative investments. By holding a well-balanced mix of assets, insurers can reduce their exposure to investment risks and better align their assets with their liabilities. Moreover, a wide array of financial products, such as derivatives, is available to hedge various market risks. Developed markets also tend to have deep long-term debt markets, allowing life insurers to invest in long-duration bonds that match their long-term liabilities.

⁴¹⁹ European Commission (1999). *Rebuilding Pensions, Security, Efficiency, Affordability - Recommendations for a European Code of Best Practice for Second Pillar Pension Funds*, prepared by Pragma Consulting, Brussels, p. 19.

⁴²⁰ Shindo, T., & Stewart, F. (2021). *Developing Insurance Markets: Insurance companies and infrastructure investments*. Washington, DC: World Bank Group, p. 23.

For instance, the availability of 20- or 30-year government and corporate bonds enables insurers to lock in stable returns over time and mitigate reinvestment risk.

Furthermore, developed markets ensure greater liquidity, which facilitates short-term liability management. High liquidity and transparency in developed markets also support more efficient security pricing, enabling insurers to make well-informed investment decisions and accurately assess portfolio risks and returns.⁴²¹ All these factors allow insurers operating in countries with developed financial markets to optimise their investment strategies, supporting both higher investment income and stronger solvency positions over the long term.

In underdeveloped financial markets (common in many emerging and developing economies), by contrast, insurers encounter a much narrower range of investment options. These markets are often characterised by shallow equity exchanges, illiquid secondary trading of domestic government bonds, and limited corporate bond issuance. In such environments, insurers tend to concentrate their assets in a few traditional categories, primarily domestic government bonds, bank deposits and other fixed-income instruments, simply because suitable alternatives are lacking.

Moreover, insurers in many emerging markets face significant mismatches between assets and liabilities. The main obstacles to effective asset and liability management (ALM) are the shortage of long-term fixed-income instruments and the limited liquidity of local bond and equity markets.⁴²² The scarcity of derivatives, such as interest rate and currency swaps, further constrains insurers' ability to manage market risks effectively.

Because they are constrained mainly to bonds and cash, as assets that are generally safer but offer lower yields, insurers in underdeveloped financial markets face limited opportunities to enhance investment returns. As a result, their ability to optimise the risk-return trade-off may be considerably reduced compared to insurers operating in more developed financial environments.

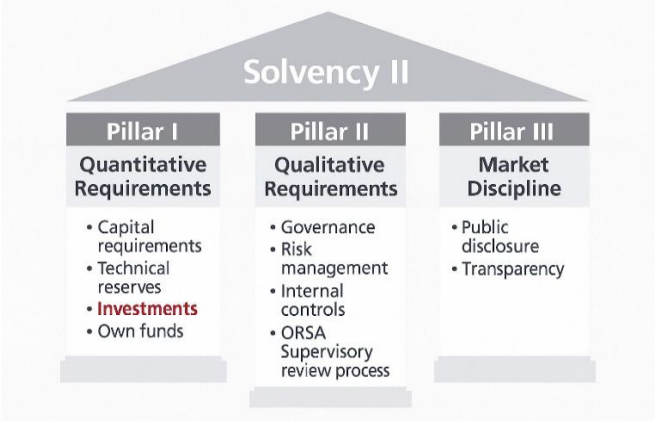
⁴²¹ Poufinas, T., & Siopi, E. (2024). Investment Portfolio Allocation and Insurance Solvency: New Evidence from Insurance Groups in the Era of Solvency II. *Risks*, 12(12), p. 21.

⁴²² Singh, M., & Kong, J. (2005). Insurance Companies in Emerging Markets, *IMF Working Paper*, No. 88, Washington, DC: International Monetary Fund, p. 11.

3. INVESTMENT REGULATION AND PRACTICE UNDER THE SOLVENCY II FRAMEWORK

Solvency II, the comprehensive regulatory framework governing the European insurance market, was introduced in 2016 to enhance policyholder protection and ensure the financial soundness of insurance undertakings. It is built upon a three-pillar structure comprising quantitative requirements, qualitative requirements, and disclosure and transparency. Insurers’ investment activity plays a crucial role within this framework, as it is incorporated into Pillar I, alongside the rules for calculating capital requirements and technical reserves (Figure 1).

Figure 1. The three-pillar structure of the Solvency II framework



Source: Adapted from Swiss Re (2006). *Solvency II: an integrated risk approach for European insurers*. Sigma, 4/2006, Zürich: Swiss Re, p. 8.

One of the most significant innovations introduced by Solvency II in the regulation of insurers’ investments is the adoption of the prudent person rule. Under the prior Solvency I regime, insurance laws contained lists of admissible assets and percentage ceilings, i.e. insurers were allowed to cover their technical reserves only with certain approved asset types (e.g. government bonds, rated corporate bonds, listed equities, real estate), and only up to fixed limits. Additionally, the pre-Solvency II regulation applied only to assets covering technical provisions (as opposed to all assets).⁴²³

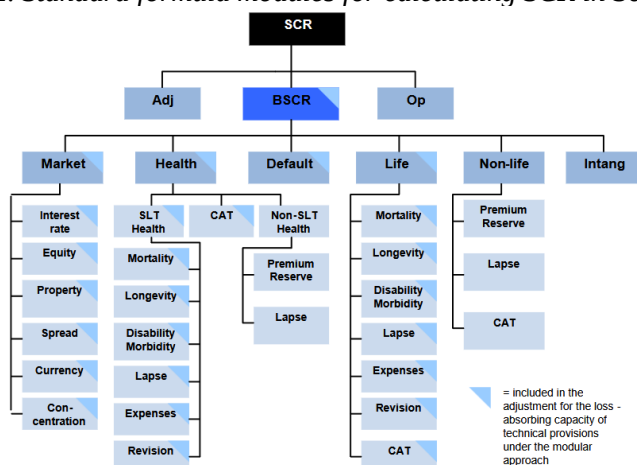
Solvency II eliminated these decades-old, strict quantitative rules, granting insurers greater freedom in managing their investment portfolios, provided they adhere to sound risk management practices. Insurers must ensure that assets are

⁴²³ Chaplin, R. A. et al. (2024). *The Standard Formula: A Guide to Solvency II*. New York: Skadden, Arps, Slate, Meagher & Flom LLP, p. 84.

invested in a manner appropriate to the nature and duration of their liabilities, and that investment decisions take into account the security, quality, liquidity, and profitability of the portfolio as a whole.⁴²⁴ This includes ensuring appropriate diversification, avoiding excessive exposure to single issuers, and conducting investments only in assets whose risks can be properly identified, measured, monitored, managed, controlled, and reported.⁴²⁵

In parallel with the shift toward qualitative standards in regulating investment activities, Solvency II imposes quantitative capital requirements to cover investment-related risks. The market risk module is a key component of an insurer's overall Solvency Capital Requirement (SCR) (Figure 2). It captures the risk of a decline in own funds due to changes in market variables such as equity prices, property values, interest rates, credit spreads, and exchange rates. These risks are measured through the standard formula or an internal model approved by the supervisory authority. The market risk module of the SCR calculation is directly affected by the structure of an insurer's investment portfolio, incentivising risk-sensitive asset allocation and diversification.

Figure 2. Standard formula modules for calculating SCR in Solvency II



Source: European Insurance and Occupational Pensions Authority (2014). *The underlying assumptions in the standard formula for the Solvency Capital Requirement calculation*. Frankfurt am Main: EIOPA, p. 6.

⁴²⁴ Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II). *Official Journal of the European Communities*, 2009/138/EC, article 132.

⁴²⁵ Ibid.

The standard formula involves the application of prescribed shocks calibrated to reflect extreme but plausible market scenarios for each market risk sub-module. For instance, the interest rate risk sub-module applies both upward and downward shifts to the yield curve. The capital requirement for each sub-module is derived by measuring the change in the value of the insurer's own funds between the base and shocked scenario. The overall capital requirement for market risk is then calculated by aggregating the capital charges from individual sub-modules using a predefined correlation matrix:⁴²⁶

$$SCR_{Market} = \sqrt{\sum_i \sum_j Corr_{i,j} \cdot SCR_i \cdot SCR_j} \quad (1)$$

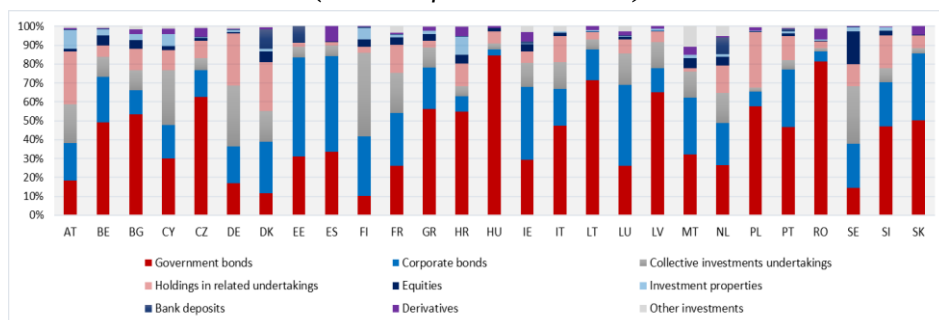
where:

SCR_i - capital requirement for market risk sub-module i ,

$Corr_{i,j}$ - correlation coefficient between sub-modules i and j .

Although the prudent person rule allows insurers flexibility in investment decisions, the SCR imposes a quantitative capital charge based on the risk profile of those investments. This dual regulatory approach incentivises insurers to pursue investment strategies that optimise returns while maintaining capital adequacy and solvency. In addition to investment risk quantification, Solvency II requires insurers to conduct stress testing and scenario analysis to assess portfolio resilience and to implement hedging strategies to mitigate volatility.

Figure 3. Investment portfolio structure of EU insurers by country (data as of December 2024)



Source: Prepared by the authors based on data from

https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en#balance-sheet

⁴²⁶ Commission delegated regulation (EU) 2015/35 of 10 October 2014 supplementing Directive 2009/138/EC of the European Parliament and of the Council on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II). *Official Journal of the European Union*, L 12, article 164.

Despite the common regulatory framework under Solvency II, investment practices vary significantly across European countries. Figure 3 shows the structure of insurers' investment portfolios in EU member states at the end of 2024. In some of the observed countries, investments are heavily concentrated in government bonds, with limited exposure to other asset classes. In contrast, insurers operating in countries with more developed financial markets seem to exhibit a more diversified asset mix, including equities, investment funds, real estate, and derivatives.

To explore the differences in portfolio concentration depending on the level of financial market development, EU member states are divided into two groups. The first group includes countries with well-developed financial markets (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and Sweden), while the second group comprises those considered to have less developed financial markets (Bulgaria, Croatia, Cyprus, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia).⁴²⁷

Table 2. Summary statistics of portfolio concentration indicators

EU member states with well-developed financial markets					
Indicator	Mean	Median	St.Dev.	Skewness	Kurtosis
HHI	2,636	2,604	600.90	0.1449	1.7953
CR3	78.24%	80.55%	8.11%	-0.3673	1.7809
Bonds share	56.12%	54.20%	16.53%	0.0608	1.3482
Government bonds share	29.10%	26.23%	15.49%	0.4412	1.7590
EU Member States with less developed financial markets					
Indicator	Mean	Median	St.Dev.	Skewness	Kurtosis
HHI	4,061	3,820	1467.54	0.7886	2.9175
CR3	86.77%	90.16%	7.26%	-0.6367	1.7473
Bonds share	73.19%	77.19%	12.12%	-0.5925	2.4856
Government bonds share	54.49%	55.47%	16.93%	0.0824	2.2545

Source: Authors' calculations based on data from <https://www.eiopa.europa.eu>

Table 2 provides summary statistics of portfolio concentration indicators for the two groups of countries in Q4 2024, including the Herfindahl-Hirschman Index (HHI), based on the distribution of asset classes within insurers' investment portfolios; the concentration ratios for the top three (CR3) asset classes; and the shares of government bonds and total bonds. As shown, insurers operating in EU member states with less developed financial markets tend to exhibit, on average,

⁴²⁷ The classification relies on commonly used indicators, including capital market size, liquidity, and availability of financial instruments, drawing on sources such as the European Commission's financial development reports and EIOPA data.

higher concentration (i.e., lower diversification) in their investment portfolios. They also exhibit different variability across countries, and, for most indicators, larger asymmetry (skewness) in portfolio concentration compared to insurers in well-developed financial markets.

To examine differences in portfolio concentration indicators between two groups of EU member states, the non-parametric Mann-Whitney test and the Brunner-Munzel test are employed.⁴²⁸ Since the former test is based on the assumption of homogeneity of variances, whereas the latter does not require it, tests for equality of variances are first performed for each indicator before testing the differences in portfolio concentration.⁴²⁹ The results are presented in Table 3.

Table 3. Testing results for equality of variances

Indicator	Levene F statistic (p-value)	Brown-Forsythe F statistics (p-value)	
	W_0	W_{50}	W_{10}
HHI	4.39462 (0.04634)	3.03530 (0.09376)	4.03292 (0.05554)
CR3	0.48948 (0.49062)	0.28121 (0.60058)	0.50608 (0.48343)
Bonds share	4.27473 (0.04918)	3.31659 (0.08057)	4.09831 (0.05373)
Government bonds share	0.00431 (0.94818)	0.03982 (0.84344)	0.01087 (0.91777)

Note: W_0 - Levene mean-based test statistic robust to violation of normality assumption; Brown and Forsythe statistics based on robust estimators of central tendency instead of mean: W_{50} and W_{10} – statistics based on the absolute deviations of observations from the median and 10% trimmed mean of each group, respectively.

Source: Authors' calculations based on data from <https://www.eiopa.europa.eu>

For HHI and total bond share, the value of the mean-based Levene statistic (W_0) indicates notable variance differences at the 5% level, whereas the robust Brown-Forsythe test statistics based on median and 10% trimmed mean (W_{50} and W_{10}) suggest differences at the 10% significance level. On the other hand, in the case of the concentration ratios of the top three asset classes and the government bonds share, none of the three tests shows significant variance differences (Table 3). Given these findings, the following analysis is based on both the Mann-Whitney

⁴²⁸ In general, the Mann-Whitney test is used to examine whether the two populations have the same distribution (identical in shape and spread), whereas the Brunner-Munzel test does not require the assumptions of equal variances or identical distributions. See more in: Brunner, E., & Munzel, U. (2000). The Nonparametric Behrens-Fisher Problem: Asymptotic Theory and a Small-Sample Approximation. *Biometrical Journal*, 42, pp. 17-25.

⁴²⁹ Brown, M. B., & Forsythe, A. B. (1974). Robust tests for the equality of variances. *Journal of the American Statistical Association*, 69, pp. 364-367.

and Brunner-Munzel tests. Additionally, the Brown-Mood median test is employed to examine differences in the medians of observed indicators between the two groups of EU member states, with testing results in Table 4.

Table 4. Testing results for portfolio concentration differences

Indicator	Mann-Whitney U statistic (p-value)	MW prob.*	Brunner-Munzel statistic (p-value)	BM prob.*	Median test – Fisher exact p-value
HHI	160.0 (0.0008)	0.879	5.61 (0.000)	0.8712	0.001
CR3	146.0 (0.0063)	0.802	3.42 (0.002)	0.8022	0.016
Bonds share	143.5 (0.0095)	0.788	3.28 (0.003)	0.7885	0.087
Government bonds share	164.5 (0.0001)	0.904	7.19 (0.000)	0.9038	0.005

Note: For Mann–Whitney and Brunner–Munzel tests, both the value of test statistic and exact p-value for small samples are reported. Median test p-values are 1-sided Fisher’s exact probabilities, since at least one expected count was less than 5.

* Estimated probability that a randomly chosen value of the indicator from the group of less-developed financial markets is greater than the value from the group of well-developed financial markets.

Source: Authors’ calculations based on data from <https://www.eiopa.europa.eu>

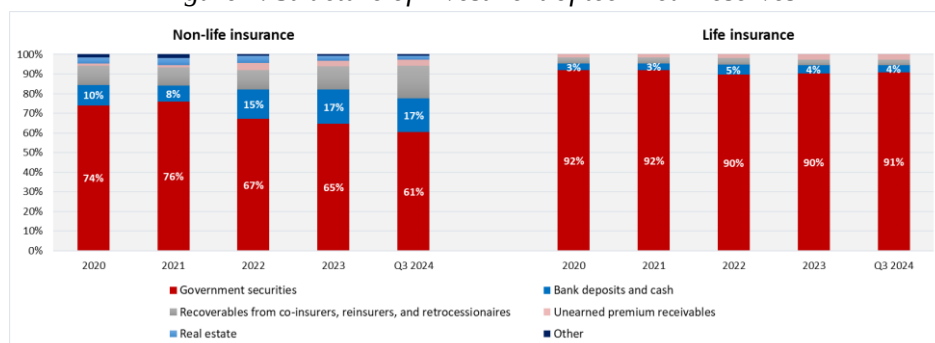
According to the results of the two non-parametric tests, it can be concluded that the differences in all four portfolio concentration indicators are significant between the two groups of countries at a 1% significance level, indicating a substantial gap in the distributions. These findings are further supported by the results of the median test, based on 1-sided Fisher’s exact p-values. Median values are higher in less-developed financial markets for the Herfindahl–Hirschman index and government bonds shares at the 1% level, while for CR3 at the 5% level, and for total bonds shares at the 10% significance level. Furthermore, both the estimated Mann-Whitney and Brunner-Munzel probabilities, varying from 0.79 to 0.90, indicate considerably higher portfolio concentration (i.e., lower diversification) among insurers operating in EU countries with less-developed financial markets than in well-developed ones. All previous findings from the analysis of EU member states confirm that, even within a harmonised regulatory framework, portfolio composition varies significantly across financial markets with different levels of development.

4. INVESTMENT OPPORTUNITIES AND CONSTRAINTS FOR INSURANCE COMPANIES IN SERBIA

Insurance companies operating in Serbia are required to hold the assets covering technical reserves in accordance with quantitative portfolio regulations that define both eligible asset types and maximum exposure limits. Limits are defined as percentages of the value of technical reserves, both for total exposures to a particular asset class and for exposures to a single issuer (Table 5). Foreign placements of assets covering technical reserves are permitted only under restrictive conditions, requiring prior approval from the National Bank of Serbia and limited to 25% of the minimum prescribed monetary amount of the insurer's share capital.⁴³⁰

The structure of assets covering the technical reserves of Serbian insurance companies varies depending on the type of insurance (Figure 4). According to data for Q3 2024, non-life insurance technical provisions of all insurers were primarily invested in government securities (60.5%), bank deposits and cash (17.1%), and recoverables from co-insurers, reinsurers, and retrocessionaires (16.6%). Over time, the share of government securities has gradually declined, while the shares of the other two asset categories have increased.⁴³¹ By contrast, the investment portfolio of life insurers is more concentrated, and its structure has remained relatively stable over time. The largest portion of the portfolio (91% as of Q3 2024) is allocated to government securities.⁴³²

Figure 4. Structure of investment of technical reserves



Source: Prepared by the authors based on data from <https://www.nbs.rs>

⁴³⁰ Law on Insurance, *Official Gazette of the Republic of Serbia*, No. 139/2014, 44/2021, article 137.

⁴³¹ National Bank of Serbia (2024). *Insurance sector in Serbia: third quarter report 2024*, Belgrade: National Bank of Serbia, p. 10.

⁴³² *Ibid*, p. 11.

Table 5. Types of assets eligible to cover the technical reserves of insurance companies in Serbia

Types of assets	Limitations in relation to technical reserves	
	Individual investments	Total investments
Securities issued or guaranteed by the Republic of Serbia, EU, or OECD member states, or their central banks	Without limitations	
Securities issued by international financial organisations of which the Republic of Serbia is a member	Without limitations	
Securities issued or guaranteed by autonomous provinces or local government units	≤ 35%	≤ 10%
Debt securities traded on the organised domestic market	≤ 35%	≤ 5%
Debt securities not traded on the organised market, issued by a domestic legal entity	≤ 3%	≤ 0.5%
Shares traded on the organised domestic market	≤ 25%	≤ 5%
Shares not traded on the organised market, issued by a domestic legal entity	≤ 5%	≤ 1%
Equity stakes in companies based in the Republic of Serbia	≤ 5%	≤ 1%
Investment units of investment funds (only for life insurance linked to investment funds)	≤ 100%	≤ 50%
Real estate and other real property rights	life	≤ 30%
	non-life	≤ 10%
Deposits with banks in the Republic of Serbia	life	≤ 20%
	non-life	≤ 7%
Cash in currency, coins, or bank accounts	life	≤ 20%
	non-life	≤ 5%
Recoverables from co-insurers, reinsurers, and retrocessionaires in non-life insurance	life	≤ 7%
	non-life	≤ 5%
Unearned premium receivables	non-life	≤ 10%
Investment units of open-ended alternative investment funds	non-life	≤ 5%
Policy loans secured by the surrender value of life insurance contracts	mathem. reserve	≤ 20%

Source: Prepared according to Decision on Investment of Insurance Funds, Official Gazette of the Republic of Serbia, No. 55/2015, 111/2017, 149/2020, 137/2022 and 82/2024, articles 3-5.

The structure of assets covering insurers' technical reserves indicates the dominance of government bonds (particularly in life insurance), a significant presence of other forms of admissible assets beyond those explicitly defined by law (primarily recoverables from co-insurers, reinsurers, and retrocessionaires in non-life insurance), and a general underutilisation of the full range of investment possibilities permitted under regulatory limits. Instruments such as money market securities, municipal bonds, corporate bonds, equities, and investment fund units are practically absent, while the share of real estate remains well below the permitted maximum. Thus, quantitative portfolio regulations do not, in practice, determine the actual composition of Serbian insurers' investment portfolios. Rather, the main constraints on insurers' investment activity stem from the underdevelopment of the domestic capital market and the absence of an active money market.

Table 6. Trading activity on the Belgrade Stock Exchange – regulated market

Year	Equity trading volume (billion RSD)	Bond trading volume (billion RSD)	Number of transactions	Market capitalisation (billion RSD)
2024	3.3	33.1	19,086	472.4
2023	3.1	17.8	19,391	416.5
2022	9.9	26.8	19,945	257.1
2021	2.9	34.7	14,003	320.7
2020	3.6	43.7	15,734	287.4

Source: Prepared by the authors based on data from <https://www.belex.rs>

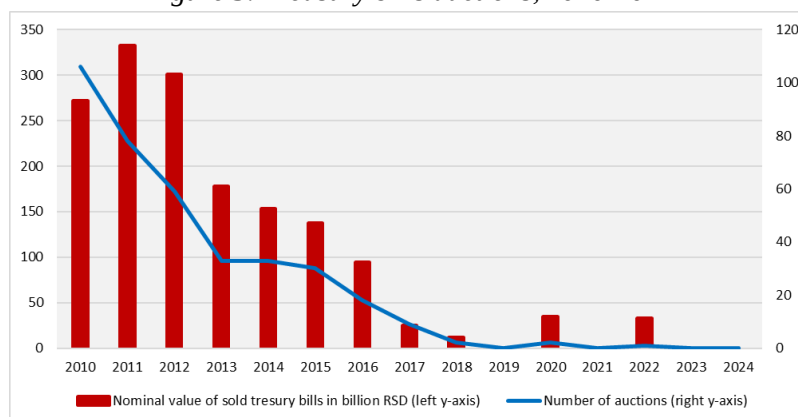
The number of shares traded daily on the Belgrade Stock Exchange is very small, and trading volumes are symbolic. Since the global financial crisis of 2008, there has been a continuous trend of companies delisting from the exchange, resulting in a steady decline in the number of available shares. In 2024, less than 10% of the total turnover on the regulated market was related to shares, while the remainder was generated by government bonds (Table 6). The total turnover on the Belgrade Stock Exchange in 2023 amounted to around RSD 20 billion, which roughly corresponds to the annual increase in insurers' technical reserves during the same year. Clearly, such trading volumes are insufficient to meet insurers' demand for eligible assets.

The Central Securities Depository registers 13 corporate bonds,⁴³³ most of which were issued under the government support program for companies during the COVID-19 pandemic. Only three issuers have listed their bonds for secondary

⁴³³ <http://www.crhov.rs/?Opcija=5&TipHartije=kratkoročne> (accessed 25.4.2025)

trading on the exchange;⁴³⁴ the rest are traded through private placements. The Capital Market Development Strategy through 2026 envisions the development of the corporate bond market in Serbia.⁴³⁵ In line with this, a primary issuance of five-year corporate bonds by a domestic private company was completed in April 2025, marking the first primary trading of financial instruments on the organised market in over a decade.⁴³⁶ However, it should be noted that a well-functioning corporate bond market requires not only credible corporations as issuers but also a strong government bond market. In Serbia, the secondary market for government bonds is not sufficiently liquid, as trading is predominantly decentralised. In 2024, only around 10% of secondary market transactions occurred on the stock exchange, while the remainder were over-the-counter (OTC).⁴³⁷ As for other long-term instruments, no municipal bonds are currently in circulation. Moreover, insurers in Serbia do not have access to financial derivatives for hedging market risks.

Figure 5. Treasury bills auctions, 2010-2024



Note: Euro-denominated treasury bill values were converted to dinars at the official middle exchange rate on the issuance date.

Source: Prepared by the authors based on data from <https://javnidug.gov.rs>

Among money market instruments, only treasury bills are issued in Serbia. However, their issuance has been declining (Figure 5). Over the past five years, they have been issued only three times - once in 2022 and twice in 2020.⁴³⁸ These

⁴³⁴ https://www.belex.rs/trzista_i_hartije/hartije/obv (accessed 25.4.2025)

⁴³⁵ Capital Market Development Strategy for the Period 2021-2026, *Official Gazette of the Republic of Serbia*, No. 102/2021

⁴³⁶ <https://www.belex.rs/trgovanje/vesti/100476> (accessed 24.4.2025)

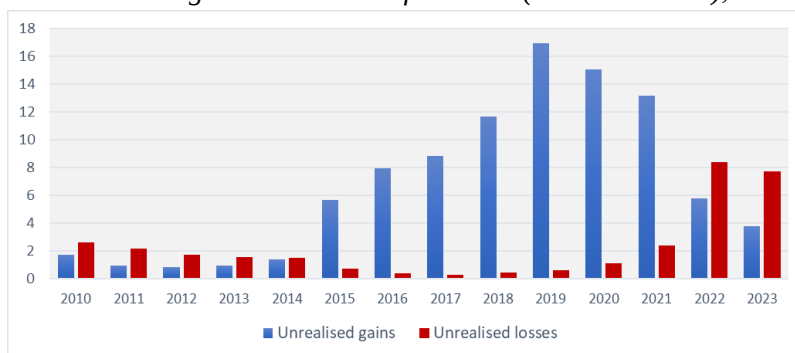
⁴³⁷ Authors' calculations based on data from <https://javnidug.gov.rs/rsc/tistorijsko>.

⁴³⁸ <https://javnidug.gov.rs/rsc/istpregledprimtrgovanja> (accessed 24.4.2025)

securities have since matured and are no longer in circulation. Other types of money market instruments, such as commercial papers, certificates of deposit, and bankers' acceptances, are virtually nonexistent. The availability of such instruments would be highly beneficial for insurers, primarily because they are important for maintaining liquidity. Furthermore, treasury bills are theoretically the only instruments that provide complete protection against inflation risk. As short-term instruments maturing every few months, they enable proceeds to be regularly reinvested at current market interest rates. In contrast, long-term bonds, when held to maturity, lock in yields determined at the time of issuance, which may be lower than prevailing rates later on.⁴³⁹

Given the underdevelopment of the domestic financial market, insurance companies are effectively constrained to rely on government bonds as the main financial instrument for covering their technical reserves. However, the pronounced concentration in government securities raises concerns regarding insurers' exposure to interest rate risk and the potential sensitivity of their financial position to both upward and downward movements in interest rates.

Figure 6. Unrealised gains and losses of insurers (in RSD billions), 2010-2023



Source: Prepared by the authors based on data from

https://www.nbs.rs/sr_RS/finansijske-institucije/osiguranje/poslovanje/

The rise in interest rates leads to a decline in the market value of existing bonds in portfolios classified as available for sale, resulting in unrealised capital losses, which will be realised if the bonds are sold before maturity.⁴⁴⁰ During the most

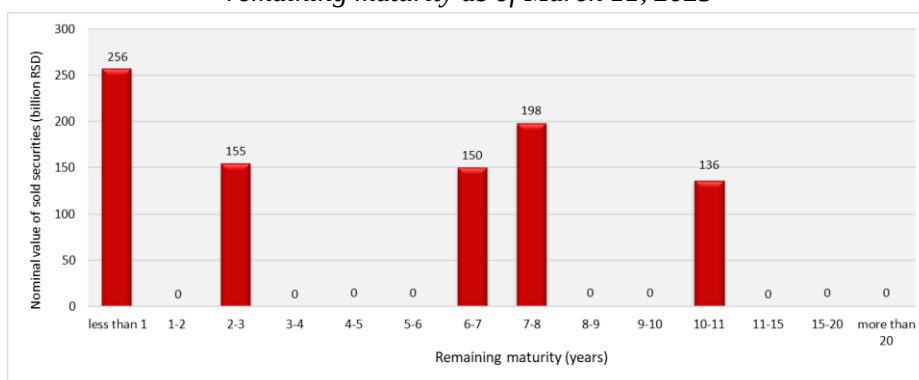
⁴³⁹ Koprivica, M. (2022). The impact of inflation risk on life and non-life insurers. In: *Development of modern insurance market – constraints and possibilities*, Kočović et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 255-271.

⁴⁴⁰ See more in: Kočović, J., Koprivica, M., & Mitrašević, M. (2024). Impact of rising interest rates on insurance companies. In: *Transformation of the insurance market –*

recent phase of interest rate increases in 2022 and 2023, insurers in Serbia recorded unrealised losses that significantly exceeded unrealised gains, thereby reducing their capital levels (Figure 6).

Declining interest rates also pose a threat to the capital adequacy of insurers. When interest rates fall, the value of assets increases (due to the dominance of fixed-income instruments), but the present value of insurers' liabilities also rises. If assets and liabilities were perfectly matched in terms of maturity, their values would increase at the same rate, leaving the capital position unchanged. In practice, however, this is rarely the case due to the general scarcity of long-term fixed-income instruments (i.e., with maturities exceeding 10 years). Most life insurers exhibit a negative duration gap, meaning that the maturity of their liabilities exceeds that of the assets intended to cover those liabilities. As a result, liabilities are more sensitive to interest rate changes; therefore, when rates rise, the increase in the present value of liabilities exceeds the increase in the value of assets, leading to a reduction in the insurer's available capital.⁴⁴¹

Figure 7. Outstanding government securities denominated in dinars by remaining maturity as of March 11, 2025



Source: Prepared by the authors based on data from <https://javnidug.gov.rs/rsc/istprebledprimtrgovanja>

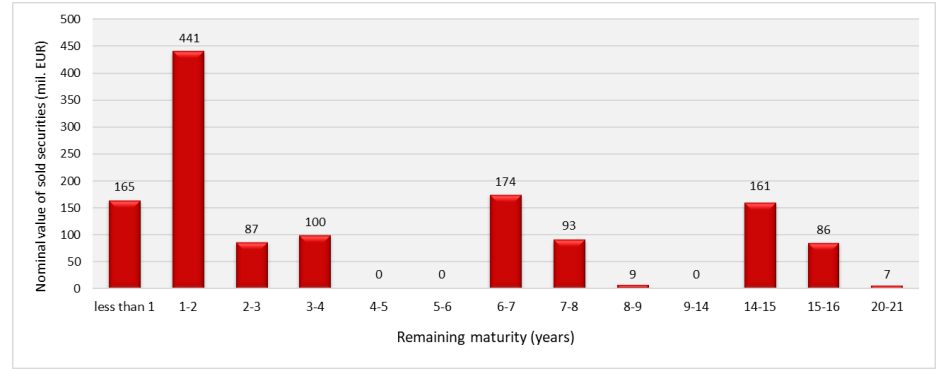
Figure 7 shows the maturity structure of outstanding dinar-denominated government bonds as of March 11, 2025. Nearly 30% of the total nominal value matures within one year, and an additional 17% falls into the two-to-three-year

responses to new challenges, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 3-21.

⁴⁴¹ Koprivica, M., & Balleer, M. (2020). Prospects of the insurance sector in a low interest rate environment. In: *Insurance Market After COVID-19*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, p. 146.

bracket. There are no outstanding bonds with remaining maturities beyond eleven years. The shortage of long-term instruments significantly limits the capacity of institutional investors, especially life insurers, to invest in assets that reflect the long duration of their liabilities.

Figure 8. Outstanding euro-denominated government bonds by remaining maturity as of March 11, 2025



Source: Prepared by the authors based on data from <https://javnidug.gov.rs/rsc/istpregledprimtrgovanja>

Figure 8 depicts the maturity structure of outstanding euro-denominated government bonds, which appears slightly more diversified but remains limited in volume. Approximately 46% of these securities mature within the next two years, while those with maturities beyond 15 years account for less than 8% of the total. The total value of bonds with remaining maturities over 15 years is below EUR 100 million, which is low compared to the mathematical reserves of Serbian insurers, amounting to over EUR 1 billion at the end of 2024.⁴⁴²

This shortage of long-term government bonds across different maturities prevents insurers from building investment portfolios aligned with the duration of their liabilities, particularly in life insurance, where obligations often extend over several decades. Even under ideal conditions, where insurers could fully allocate their assets to the currently available government bonds, asset-liability duration matching would remain unachievable. The resulting duration mismatch increases insurers’ exposure to interest rate risk, undermining their capital adequacy and solvency.

* * *

⁴⁴² https://www.nbs.rs/export/sites/NBS_site/documents/osiguranje/tromesecni/T6_IV_2024.pdf (accessed 30.4.2025)

While the prudent person rule underlying Solvency II implies greater flexibility and risk sensitivity in investment regulation, its effectiveness largely depends on the maturity and depth of the financial market, as well as the institutional capacity of both insurers and regulators. In countries with less developed financial markets, weaker corporate governance and limited supervisory resources, giving insurers full investment freedom could be dangerous. In these cases, quantitative rules remain a necessary safeguard to ensure asset quality and risk control in the absence of broad diversification and advanced risk modelling capabilities.

Insurance companies in Serbia are required to cover their technical reserves with eligible assets within prescribed limits. However, the structure of their investments is primarily shaped by the reality of the domestic financial market, which remains underdeveloped across all key segments, including the money, capital, and derivatives markets. This not only hampers efficient capital allocation but also impedes asset-liability management aimed at mitigating interest rate, currency, and liquidity risks. In such conditions, insurers cannot fully assume their role as institutional investors. Therefore, the main constraint on their investment activity stems not from regulatory rules, but from market underdevelopment.

Chapter 15.

EXCHANGE RATE RISK INSURANCE

International trade is a very dynamic business activity connected to all sorts of risks due to its transnational character. Doing business across national borders carries additional risks compared to a business that operates on a single national market. These additional risks include differences in legal regimes and business climate, different currencies, business language differences, cultural differences of businessmen, etc. That is why many business authors see internationalisation of a company as a big leap forward in its business development, but also connected to greater risks. But greater risks are almost always connected to greater profits, and that is the main stimulation of companies to do business abroad.

International businesses usually face two groups of risks: commercial risks and non-commercial risks. Commercial risks are connected to the economic factors of business operations and can include risks of lost payments, bankruptcy risks, foreign exchange rate risks, etc. All of these risks are a part of normal business activity, and companies are able to successfully deal with them. Non-commercial risks, in contrast, are based on non-economic factors like political, cultural, ecological, etc. These risks are more unpredictable and are not directly linked to a business activity, but their effects on international business activity can be significant. Many companies are not prepared and able to avoid and survive non-commercial risks, and the help of other institutions, like banks, is absent in the case of these risks. On certain occasions, states are prepared to help their companies deal with non-commercial risks. Examples of this help are financing and insurance of export credits by state export credit agencies.

But the greatest risk in international business comes from exchange rate fluctuations that causes sevier risk. If a company earns a profit in international business in one currency, it can siverely decrease this profit, or even have a loss, in exchanging the profits to another currency, due to a high decrease of value of the first currency. We call this risk exchange rate risk.

In our chapter, we will define exchange rate risk and present the literature review on this subject. We will also describe macroeconomic, as well as microeconomic, instruments that can help companies to be insured against exchange rate risks in international trade.

1. EXCHANGE RATE RISKS IN INTERNATIONAL TRADE

One of the risks associated with foreign trade is the uncertainty of future exchange rates. The relative values of the two currencies could change between the time the business deal is concluded and the time payment is received. If companies are not properly protected, a devaluation or depreciation of the foreign currency could cause them to lose money from this international business deal. The United States International Trade Administration defines foreign exchange risk as the exposure to potential financial losses due to depreciation of the foreign currency against the U.S. dollar.⁴⁴³ Foreign exchange risk refers to events abroad that affect the net income of a domestic enterprise and can affect nearly all enterprises in a global economy. Foreign exchange risk is a wider term used to cover all the foreign transactions that can bring a risk to a company's operation overseas, for example, a recession in a foreign market that adversely affects sales of domestic vendors to foreign buyers.⁴⁴⁴ But the main cause of this general risk is a change in the exchange rate of currencies.

Exchange rate risk refers to the risk that a company's operations and profitability may be affected by changes in the exchange rates between currencies. The notion of foreign exchange risk is limited here to financial transactions involving two or more currencies. The general definition of exchange rate risk is that it "relates to the effect of unexpected exchange rate changes on the value of the firm"⁴⁴⁵.

Exchange rate risk consists of several factors:

- Transaction exposure, which arises from the effect that exchange rate fluctuations have on a company's obligations to make or receive payments denominated in foreign currency, and this type of exposure is short-term to medium-term in nature;
- Translation exposure arises from the effect of currency fluctuations on a company's consolidated financial statements, particularly when it has foreign subsidiaries, and this type of exposure is medium-term to long-term;
- Economic (or operating) exposure is caused by the effect of unexpected currency fluctuations on a company's future cash flows and market value and is long-term in nature. The impact can be substantial, as unanticipated

⁴⁴³ US International Trade Administration, www.trade.gov/foreign-exchange-risk

⁴⁴⁴ Mange, J. I. (2000). Measuring Foreign Exchange Risk in Insurance Transactions. *North American Actuarial Journal*, 4(2), pp. 88-100, doi: 10.1080/10920277.2000.10595905

⁴⁴⁵ Madura, J. (1989). *International Financial Management*. 2nd ed., St. Paul, MN: West Publishing Company.

exchange rate changes can greatly affect a company's competitive position, even if it does not operate or sell overseas, but it imports its inputs.⁴⁴⁶

We can calculate exposure to exchange rate risk in several ways. One is using regression, where the value of a foreign asset or overseas cash flow fluctuates as the exchange rate changes. A regression analysis of the asset value (P) versus the spot exchange rate (S) should produce the following regression equation:

$$P = a + (b * S) + e ,$$

where: P - Asset value, A – regression constant, B – regression coefficient, S – spot exchange rate and E – random error.

The regression coefficient *b* is a measure of economic exposure and measures the sensitivity of the asset's dollar value to the exchange rate.⁴⁴⁷

$$b = \frac{Cov(P, S)}{Var(S)}$$

Multinational firms are participants in currency markets by virtue of their international operations. To measure the impact of exchange rate movements on a firm that is engaged in foreign-currency denominated transactions, the other methodology is used - value-at-risk (VaR) from exchange rate moves.⁴⁴⁸

Governments tend to create stable business environments in order to create jobs and draw foreign investment. In some countries they tend to adopt fixed exchange rates or even pay premiums to importers on the exchange rate they receive. But all these measures require a lot of financial means that many countries lack. That is why many of them have turned to international organisations for help.

In order to decrease risks in international trade, countries have agreed to establish an international economic organisation as an important international legal instrument. In the area of international trade, the most significant international intergovernmental organisation is the World Trade Organisation (WTO). The basic principles of the WTO guarantee non-discrimination and predictability in

⁴⁴⁶ Picardo, E. (2023). Exchange Rate Risk: Economic Exposure. *Investopedia.com*, August 16, <https://www.investopedia.com/articles/forex/021114/exchange-rate-risk-economic-exposure.asp>.

⁴⁴⁷ Ibid.

⁴⁴⁸ Hakala, J., & Wystup, U. (2002). *Foreign Exchange Risk: Models, Instruments, and Strategies*. London: Risk Publications.

trade relations of WTO member countries. The WTO agreements establish the legal framework for international trading, and these agreements have been put in place to decrease the risks of unpredictable acts of WTO member governments. But the most important achievement of the WTO is the consolidation of tariff rates and the elimination of risks from tariff escalations. Risk analysis is embedded in WTO regulations since some WTO agreements require scientific proof to be acquired when introducing border measures in international trade.⁴⁴⁹ But the achievements of the WTO in the area of exchange risk limitations were limited.

The other international organisation, founded in 1944 to manage convertibility of currencies and fix exchange rates, was the International Monetary Fund (IMF). The main function of the IMF at the beginning was to secure a system of international payments that would enable smooth international trade. The root of the IMF's mandate primarily lies in Article I of the Agreement establishing the IMF, which specifies that one purpose of the IMF is "to facilitate the expansion and balanced growth of international trade..."⁴⁵⁰ Monetary cooperation that countries have established in framework of IMF would lead to stable exchange rates and this will lead to a significant decrease in exchange rate risk for businesses operatin in international trade.

The demise of the Bretton-Woods world of quasi-fixed exchange rates in 1973 and the advent of increasingly volatile exchange rates has further compounded the task of effectively controlling for exchange risk, specially in international insurance and re-insurance treaties.⁴⁵¹ Foreign exchange risk arises naturally in insurance products when premiums are remitted in one currency but benefits are denominated in another. Demonetisation of the gold in 1973 and changes in the Bretton-Woods system of international payments and exchange rate coordination have put back the uncertainty in international business and raised the exchange rate risks.

In Europe, regional cooperation was developed, but not only in liberalising intraregional trade but also in monetary affairs. The countries of Europe have

⁴⁴⁹ Bjelić, P. (2012). World Trade Organization and the Global Risks. In: *Better Business Regulation in a Risk Society*, Alemano, A. et al. (eds.), New York: Springer Science+Business Media, pp. 193-206.

⁴⁵⁰ International Monetary Fund (2023). Review of the Role of Trade in the Work of the Fund, *IMF Policy Paper*, Washington, DC: IMF.

⁴⁵¹ Cozzolino, J. M., & Jacque, L. L. (1987). Foreign Exchange Risk in International Insurance and Reinsurance. *Managerial Finance*, 13(1), pp. 18-22. <https://doi.org/10.1108/eb013577>

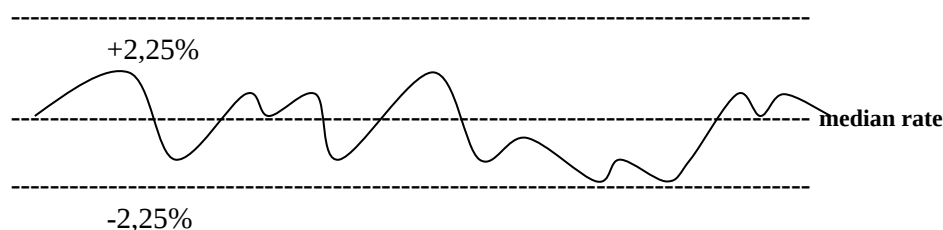
realised that trade cannot be developed without convertible national currencies and stable exchange rates. Upon recovery after the Second World War, most European countries were able to re-establish the convertibility of their currencies. Until this was achieved, they engaged in several agreements, like the Agreement on Intra-European Payments and Compensations. This payment system, established in 1948, sought to facilitate the distribution of American aid and to improve intra-European trade by balancing the balance of payments through deficit elimination. The system was based on predictions of bilateral European trade and meant that countries with a predicted balance of payments surplus would place their surplus in European countries with a deficit, while in return, they would receive aid from the USA if the surplus exceeded a certain level. Countries with a deficit received both aid from the US and aid from European countries, with a projected surplus in the currencies of those countries. This system, based on compensation agreements, was ineffective and misdirected funds due to erroneous forecasts. That is why it was abandoned and replaced by another agreement, the European Payment Union (EPU).

In 1950 seventeen countries of the Organization for European Economic Cooperation (OEEC), which was set up to distribute American aid through the Marshall Plan, that included Austria, Belgium, Greece, Denmark, Iceland, Ireland, Italy, Luxembourg, Germany (representatives of the Allied administration), Norway, Portugal, Sweden, Switzerland, the Netherlands, the United Kingdom, Turkey and France, founded the European Payments Union (EPU). The Union replaced the Agreement on Intra-European Payments and Compensation and marked the transition from bilateral cooperation to multilateralism. EPU dealt with multilateral clearing between members because, at that time, European currencies were still not convertible. The United States did not support this Union but advocated the establishment of convertibility as soon as possible (assuming obligations under Article VIII of the IMF Statute). That's why EPU was also important as a self-born European initiative. At that time, this Union was a necessity and influenced the increase in the volume of exchange between European countries and their further convergence, by decreasing exchange rate risks in intra-European trade. The Union included a mechanism of automatic credit lines for member countries with a balance of payments deficit, in a certain percentage of the quota, usually 20-25% of the quota. Mutual claims were settled once a month, and the agent of the EPU was the Bank for International Settlements (BIS) from Basel, Switzerland.

When most European currencies achieved convertibility, as defined in Article VIII of the IMF Statute, Western European countries established in 1958 the European Monetary Agreement (EMA - European Monetary Agreement). This agreement regulates the method of calculating mutual debts and claims in

payments between member countries under the conditions of convertibility, and members were most of the European countries. Compensation (clearing) of the balance of payments was carried out, but all settlements were made in gold or convertible currencies. The agreement established the European Fund for financing temporary balance of payments deficits of member countries. Countries with a balance of payments deficit were granted loans for two years, but not automatically. The goal of EMA is to encourage and develop trade between members and the convertibility of their national currencies.

Figure 1. European currency "snake"



Source: Authors' representation on provisional data

EMA and the European Fund ceased to operate on December 31, 1972 and were replaced by the European Monetary System (EMS - European Monetary System). EMS as a form of monetary cooperation of the European Community (EC, now European Union), was preceded by the Agreement on the so-called European currency "snake", concluded in 1972 in Basel. All countries have switched to floating exchange rates, but within the limits of $\pm 2.25\%$, with the exchange rates being currency changes in relation to other currencies in the agreement. This was the first step towards a monetary union, the ideal of which is a common currency. The agreement is known as the "snake in the tunnel", but since 1973, the snake has been swimming against the dollar. Namely, in March 1973, the EEC countries made a decision on the common floating of their currencies in relation to the dollar. Now the group as a whole is regulated against the dollar, with a permissible variation of $\pm 4.45\%$. The members of the agreement were 12 countries of the European Communities - Belgium, Denmark, the Netherlands, West Germany, Great Britain, Italy and France, and countries outside the Community - Norway and Sweden. Other European countries successively became members of this agreement.

An important part of EMS was the Exchange Rate Mechanism (ERM). This mechanism implies that each national currency in the system is assigned a value in European Currency Unit (ECU), as an accounting monetary unit in EC, the so-

called central rate ("central rate"), and then the parity grid is applied. The parity grid is a table showing the relative exchange values in ECU for each pair of currencies. The values obtained in this way are compared with the market values of currencies, and the changes are kept within the limits of $\pm 2.25\%$, with the intervention starting when the change reaches 75% of the allowed limit. The stabilisation of exchange rates of European countries contributed to the faster development of intraregional trade and stabilisation of the common market. Joint floating of all national European currencies against the U.S. dollar was another factor that promotes intraregional trade rather than intercontinental trade, since the fixed relations between exchange rates in Europe have eliminated exchange rate risk in intraregional trade of European companies. The ERM stabilised European currencies, and they floated together against the dollar and yen, and this is considered the beginning of monetary integration in Europe.

But the most important monetary arrangement in the European Union was the establishment of the Monetary Union (so-called Economic and Monetary Union – EMU) and the introduction of the single currency – EURO. Back in 1969, at the Summit in The Hague, the possibility of creating an EC monetary union was examined. Improving business conditions through the stabilisation of currencies embodied in various monetary agreements was not enough. At the European Council held in June 1988, it tasked the committee chaired by Jacques Delors, then President of the Commission, to prepare a report on the creation of a monetary union. As a result of the work of this committee, the Delors report followed, which predicted the creation of a monetary union in three stages.

The first phase of the establishment of the monetary union began on July 1, 1990, and included: removal of remaining restrictions on the movement of capital, increasing coordination in the area of economic policies of member states and intensive cooperation between the central banks of member countries. The second stage began on January 1, 1994, with the establishment of the European Monetary Institute (EMI). The EMI led to monetary integration, but it had no competence in conducting monetary policy in the EU. Its main tasks were strengthening the cooperation of central banks and the coordination of monetary policies, and making preparations for the creation of the European System of Central Banks (ESCB). The final, third stage of the establishment of the monetary union began on January 1, 1999, when the exchange rates of the currencies of the eurozone countries for the euro were irreversibly fixed. The euro was introduced into payment transactions, and the European Central Bank (ECB) started to manage a unified monetary policy in the eurozone.

The benefits of EMU included, firstly, the elimination of exchange rate risk in intra-European trade and an increase in economic growth, but also an increase in

price stability and transparency, a reduction of interest rates in some countries, an increase in employment, and a reduction of inflation rates, especially import inflation. This all lead to significant increase in intra regional european trade, inside the EU block but also the euro become an important world currency since EU is most important trading power in the world.

2. LITERATURE REVIEW

Foreign exchange risk, also known as currency risk or exchange rate risk, arises from fluctuations in currency exchange rates that can significantly affect the financial performance of companies engaged in international transactions or operations. With the global shift from fixed to floating exchange rate regimes since the collapse of the Bretton Woods system in 1973, this risk has become a critical concern for all companies, insurers, and financial institutions. For the insurance industry, exchange rate risk is of significant importance, particularly for multinational companies - insurers, reinsurers, and trading businesses that operate across borders. Foreign exchange risk insurance is a critical component of financial risk management, particularly for insurers operating in international markets. Foreign exchange risk insurance, encompassing financial instruments and strategies such as hedging, derivatives, and reinsurance, is employed to mitigate these risks. The literature review is focused on academic research on foreign exchange risk insurance, focusing on its mechanisms, applications in the insurance industry, and challenges, in developed and to some extent in developing or emerging markets. The review draws on theoretical studies and empirical analyses to provide a comprehensive understanding of the topic.

One of the first studies that explored the "intersection" of two "research sets", namely, reinsurance and foreign exchange risk management, was presented by Cozzolino & Laurent (1987). These two areas of academic endeavours have developed along independent paths, with the risk and insurance profession mainly concerned with the selection of the "best share" of an insurance risk and the international financial management profession investigating the management of deterministic transaction and translation exposures to exchange risks. Yet international reinsurance decisions which require the assessment of exposures to two statistically independent sources of risk may well result in loss of catastrophic proportions. A conceptually sound yet operationally manageable framework based upon the expected utility theory was developed, allowing the firm to integrate explicitly the foreign exchange risk variable in international reinsurance decisions. Specifically two questions were answered in this paper: (i) given the a-priori decision of reinsuring a foreign risk, what amount of this foreign currency-denominated stochastic transaction exposure should be covered through a forward contract and (ii) given the opportunity of reinsuring alternative

"layers" of foreign insurance risk, which one should be selected after allowing for stochastic exchange rates.⁴⁵²

Seeing significant growth opportunities, many insurers are considering entering and/or expanding their presence in foreign markets. The models developed by Mange (2000) could help them quantify the magnitude of their potential foreign exchange exposure, better enabling these insurers to judge their approach to their chosen markets. The models developed do not reflect the risk associated with exchange rate regimes that are not credible. Lack of credibility exposes the insurer to a potentially highly volatile exchange rate environment, in which timing, and not spread of risk, would be the key to success. If an insurer chooses to operate in such an environment, it should establish processes to closely monitor and manage foreign exchange exposures in order to limit losses and/or capitalize on opportunities presented. The numerical examples suggest that incremental foreign exchange risk may be small in the context of shorter-term insurance risks and very large in relation to longer-term products such as whole life and annuities. Caution should be exercised before applying these results directly to specific business situations.⁴⁵³

Empirical studies on foreign exchange (FX) risk insurance can employ diverse methodologies. Cash flow-based approaches focus on transaction exposure by modelling the interplay of exchange rates with economic variables. Capital market approaches, reviewed by Akkaş (2016), quantify exposure by examining the impact of exchange rate changes on firm value, often using stock price data. Survey-based studies explore corporate hedging practices, revealing discrepancies between theoretical prescriptions and actual practices.

Qualitative case studies, like the one by Dnanani (2003) on a UK multinational in the mining industry, provide insights into the "how" and "why" of FX risk management, emphasising industry-specific factors. These studies highlight the importance of firm-level analyses to avoid aggregation biases that obscure operational and managerial differences. Using a case study approach, this paper reviews the corporate exchange risk management practices of a single large UK multinational company. The research results shed new light on the management of economic exchange rate risk and also have implications for the effects of movements in exchange rates in the context of the translation process. More generally, these results indicate that instances in which corporate practices deviate from normative prescriptions do not necessarily imply sub-optimal behaviour, although some companies may benefit from the reconsideration of

⁴⁵² Cozzolino & Jacque (1987), *op. cit.*, pp. 18-22.

⁴⁵³ Mange (2000), *op. cit.*, pp. 88-100.

their exchange risk management policies. Finally, they highlight new areas of research and also emphasise the role of qualitative research in accounting and finance.⁴⁵⁴

The theoretical foundation for managing FX risk is rooted in financial risk management literature, which emphasises the use of hedging to reduce volatility in cash flows and firm value. Akkaş provides a literature review focusing on the foreign exchange rate exposure, which is the impact of foreign exchange risk on companies' assets and liabilities. Firstly, the study tries to clarify the concept of foreign exchange exposure, and then the different models in the context of the capital markets approach to the measurement of foreign exchange rate exposure were examined in detail. Secondly, determinants of foreign exchange exposure were reviewed in general. Thirdly, the relationship between foreign exchange risk management and foreign exchange exposure is summarised.⁴⁵⁵

The insurance industry, particularly in the United States, has been a focal point for studies on foreign exchange risk due to its significant international operations. Research by Li et al. (2009) highlights that U.S. insurers, both life and non-life, face similar FX risk profiles, with no systematic differences in their exposure to currency fluctuations. This similarity suggests comparable risk management strategies driven by shared functions in risk pooling and financial intermediation. Empirical evidence indicates that many U.S. insurers are exposed to exchange rate movements, particularly with major trading partners such as the U.K., Japan, and Canada. The study employs a cash flow-based methodology, adapted from Martin and Mauer (2003), to measure transaction exposure, revealing operational and size effects that correlate with increased hedging activity.⁴⁵⁶ Martin and Mauer originally use a cash flow-oriented framework to assess the transaction and economic exposures over 1989–1998 for 107 U.S.-based MNCs, which have substantial international business in Europe. Mean absolute response coefficients (MARCs) are introduced as a measure of responsiveness for short-term and longer-term lags, as proxies for transaction and economic exposures. Their results

⁴⁵⁴ Dhanani, A. (2003). Foreign exchange risk management: a case in the mining industry. *The British Accounting Review*, 35(1), pp. 35-63.

⁴⁵⁵ Akkaş, M. E. (2016). A Literature Review on the Quantification of Foreign Exchange Exposure of Non-Financial Firms Using Capital Market Approach. *Business and Economics Research Journal*, 7(1), pp. 71-87.

⁴⁵⁶ Li, D., Moshirian, F., Wee, T., & Wu, E. (2009). Foreign exchange exposure: Evidence from the U.S. insurance industry, *Journal of International Financial Markets, Institutions and Money*, 19(2), pp. 306-320.

indicate that cash flow effects are greater for long-term lags than for short-term lags in exchange rate movements for the currencies examined.⁴⁵⁷

In emerging markets, foreign exchange risk management in insurance is constrained by limited access to sophisticated financial instruments. A study on Egyptian insurance companies by Nada & Ibrahim(2017) claim that exchange rate fluctuations generate high risk for the insurance companies in Egypt, such as bankruptcy and liquidity. The study aims to measure the foreign exchange exposure (FXE) for the life insurance companies in Egypt during the period from 2000-2016. After that, the study measures the determinants of this exposure. The problem of the study is concerned with the fluctuations of the foreign exchange rate in Egypt, which have a great effect on the financial performance. The results of the study show that the life insurance companies in Egypt were significant to the FXE; the results are robust to the choice of model design.⁴⁵⁸

Hedging is a cornerstone of FX risk insurance, with firms employing both financial and operational strategies. Financial hedging involves derivatives such as forward contracts, futures, options, and swaps, which allow firms to lock in exchange rates or cap potential losses. Al Mansoori et al. (2024) review 20 high-rated journal articles, finding that derivatives are widely used to mitigate FX risk, though their effectiveness varies based on firm size, financial leverage, and exposure levels. Operational hedging, including netting (offsetting receivables and payables in the same currency) and matching (aligning assets and liabilities in the same currency), is also prevalent, particularly when derivative markets are underdeveloped.⁴⁵⁹

⁴⁵⁷ Martin, A. D., & Mauer, L. (2003). Transaction versus economic exposure: which has greater cash flow consequences? *International Review of Economics & Finance*, 12(4), pp. 437-449.

⁴⁵⁸ Nada, M. S. I., & Ibrahim, R. E. E. M. (2017). The determinants of the Foreign Exchange Exposure in the Life Insurance Companies in Egypt: An Applied Study. *International Journal of Accounting and Financial Reporting*, 7(2), Macrothink Institute.

⁴⁵⁹ Al Mansoori, G. H., Al Sharafi, E. A., Al Mheiri, S. M., & Nobanee, H. (2024). Foreign Exchange Risk Management: A Comprehensive Literature Review and Mitigation Strategies in Floating Exchange Rate Regimes, SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4979859

3. FOREIGN EXCHANGE RISK INSURANCE FOR EXPORTING AND IMPORTING ENTERPRISES

Many trading enterprises globally face the challenge and need for more intensive expansion of their businesses in international markets as a symbol of the progression of their business development. However, new opportunities in foreign trade are accompanied by many risks. One of them is an FX risk.

Non-transferable risks can affect both financiers and users of financial resources. They are provoked by changes in the foreign exchange rate or, alternatively, by changes in national exchange regulations. This is caused by the international character of foreign trade operations. Namely, enterprises originating from different countries are faced with the need to make contracts for a joint business whose financial component would be accompanied by payment in the agreed currency. Enterprises involved in developing business with international partners often come from countries with different local currencies. Many of them are not even convertible. Their first challenge is to determine the currency in which the payment will be completed. This challenge is followed by determining the method for protecting stakeholders' interests, if they expect changes in the exchange rates, whether the stakeholder is the exporter or the importer. Currency conversions may initiate losses, too. If one enterprise, exporter or importer comes from a country with a non-convertible currency and the other partner comes from a country with a convertible currency, the first partner bears greater risk. The risk also increases if the payment is planned to be realised in some future period compared to the date of concluding the contract.

The risk is dual in nature, for the exporter and the importer. Exporter from the country with a nonconvertible currency invoices goods in convertible currency, USD, or EUR and has a strong intention to avoid the loss. This exporter has obvious fear of losing money because of currency fluctuations. That is the Currency risk, or Foreign Exchange Risk.

The financial instruments that offer the possibility of transferring the risk and the so-called financial hedging are derivatives such as forward contracts, foreign exchange futures, swaps and FX options. These derivatives are predominantly seen as foreign exchange (FX) risk mitigation tools, not as speculative instruments.⁴⁶⁰ Their role is not focused only on decreasing FX volatility, but also on decreasing enterprises' exposures to interest rate fluctuations, as well as to

⁴⁶⁰ Ogundu, P. G. (2025). The strategic implications of financial derivatives in hedging corporate exposure to global economic volatility. *World Journal of Advanced Research and Reviews*, 25(2), p. 1218, <https://doi.org/10.30574/wjarr.2025.25.2.0482>

commodity price risks.⁴⁶¹ Using these instruments, trade enterprises are allowed to determine the exchange rates today that will be used in the future moment when the actual cross-border payment occurs, and by doing so, can mitigate FX risks.

At the beginning of the new century, cross-country analyses, for the case of Chile, showed that the FX derivatives market plays an important role in decreasing the aggregate exposure to fluctuations in the FX rate.⁴⁶²

Some US analyses for their enterprises have shown the relation that exists between the size of the enterprise and the use of derivative instruments in hedging its exchange rate risk. The larger the enterprise is, the greater the orientation towards derivative instruments exists.⁴⁶³

Currency value fluctuations are caused by several factors. First of all, we can point out the constant presence of inflation in countries of exporters or importers, besides the constant changes in currency markets and some interventions of the central banks. As a consequence of these changes, exporters could receive the increased amount in future, but reduce their own profit margin. On the other side, importers could find themselves in a situation where they need more money to buy foreign currency for the payment of imported goods. The solution for overcoming currency risks is based on locking the current exchange rate for future transactions.⁴⁶⁴

This risk could be overcome, according to some opinions, in two ways:

1. Entering proper forward contract position by exporter, with fixed, forward rate, if the exporter is expecting depreciation or appreciation of the domestic currency.
2. Opening a special Foreign Currency Account, where he could deposit foreign currencies obtained from export operations, and that currency could be used

⁴⁶¹ Ibid, p. 1231.

⁴⁶² Jadresic, E., & Selaive, J. (2005). Is the FX Derivatives Market Effective and Efficient in Reducing Currency Risk? *Central Bank of Chile Working Paper*, No. 325, Central Bank of Chile, p. 32.

⁴⁶³ Papaioannou, M. (2006). Exchange Rate Risk Measurement and Management: Issues and Approaches for Firms. *IMF Working Paper*, 06(255), p. 14, doi: 10.5089/9781451865158.001.

⁴⁶⁴ BPIFRANCE, *International trade: the 5 key export risks to monitor and possible solutions*, <https://www.bpifrance.com/export-credit-agency/> (11.04.2025)

only for the payment of imports by the same enterprise. The only condition is double character of that enterprise's activities, exporting and importing.⁴⁶⁵

Protection possibilities through special transactions in the case of exchange rate changes, for exporters and importers, are numerous. The main types of transactions performed on the foreign exchange market are spot transactions and forward transactions.

In the case of a *spot* foreign exchange rate, this rate is formed through transactions on the spot foreign exchange market, where the currency is delivered immediately, almost immediately, after the transaction. In addition to numerous prompt transactions that can serve as sources of protection against foreign exchange risks, the issue of invoicing in domestic, convertible currency stands out.

Modern participants in international business often conclude forward contracts. *Forward* foreign exchange transactions are performed on the forward foreign exchange market and include transactions for the delivery of currency on a precisely determined date in the future, according to the exchange rate specified at the time of concluding that transaction. Often, the maturities of the forward contracts that are OTC instruments are three months, or six months, or some other agreed-upon period and on the maturity day, the contracted transaction will be finally executed. It is mostly about shorter deadlines, up to a year.

Swap transactions are realised by combining spot and forward transactions. These transactions imply one contract for the combined purchase and sale of currency, so with this contract, currency is bought on the spot and sold on the forward market and *vice versa*.

Foreign exchange futures differ from forward contracts that are not standardised in their structure, precisely because they are standardised contracts. These contracts are similarly used to regulate payment for traded goods in foreign currency, which will be realised at a specified date in the future, at a price which is fixed and specified according to the exchange rate valid on the purchase day. This is a useful instrument to lock in an exchange rate for some period of time,

⁴⁶⁵ Bhatia, R., *Types of Risks faced by the Exporter and how to mitigate such risks*, <https://www.linkedin.com/pulse/types-risks-faced-exporter-how-mitigate-ravi-bhatia--32f1f/> (10.04.2025)

usually a short period, not longer than a year, especially usable in trade and for multinational companies. That way, they hedge foreign currency fluctuations.⁴⁶⁶

It is often used by both stakeholders in international trade, exporters as well as importers. Importers with the obligation to pay for goods bought abroad in the future need to obtain foreign currency at a future point in time. Instead of buying foreign currency at that time, they decided to use foreign exchange futures. That brings them to the position of a protected side concerning the possible volatility of the exchange rate. At the time, they need to pay in foreign currency; in the future, they will get a guaranteed exchange rate based on the FX futures contract.

Exporters, expecting the cash inflow after concluding a trade agreement and goods delivery in the future, could be found in a position of endangered interests if the exchange rate changes. That is the situation for futures to protect the value they will receive. An export enterprise in that situation will take a short position in foreign exchange futures to avoid the possible volatility of the exchange rate.

Among standardised contracts for the protection against FX risks, such as FX futures, Foreign Exchange Options could also be observed, as another sort of standardised contract. Options are derivatives, often standardised contracts like FX futures. Options give the right to buy or sell foreign currency on a specific day in the future, the expiration day, at a so-called strike price. That price is an exchange rate for the realisation of the option. But they do not represent an obligation to do so when the time comes. The stakeholder could give up the purchase or sale.

While the exporter agrees to sell the foreign currency, the importer agrees to purchase foreign currency. Options are standardised contracts used by exporters to sell foreign currency at a specific future date, but they could choose not to execute that sale. They have a right to sell, but not the obligation. The same applies to the importers' purchase of foreign currency. Depending on whether foreign currency has been sold or bought, that is, whether it is an exporter or an importer, options could be puts and calls. These options should be exercised until the expiration date or on that date. After that date, the option is not valid any more. The decision to sell or buy foreign currency at the strike price will be determined based on the exchange rate when the option expires.⁴⁶⁷

⁴⁶⁶ Hayes, A., Scott, G., & Courage, A. (2022). What Are Currency Futures? How They Work in Trade and Investing? *Investopedia.com*, May 24, <https://www.investopedia.com/terms/c/currencyfuture.asp> (10.04.2025)

⁴⁶⁷ Kozomara, J. (2019). *Finansiranje međunarodnog poslovanja*. Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 117-119.

Selling or buying a certain amount of currency should be realized according to a fixed exchange rate on the expiration or maturity date. That is the main rule for European options. In addition to this group of options, there are two more: American and Bermuda options.

Both American and European options are present on the stock exchanges. They differ from each other depending on whether they must be exercised by a certain date, or exactly on that day called the expiration date. If they must be exercised exactly on an expiration day, they are European options, and if they are allowed to be exercised on any day up to and including the expiration date, they are American options. European options give less flexibility in handling options, compared to American options. Concerning that factor, European options are considered less valuable than similar American options.⁴⁶⁸

There is also a middle solution for options between European and American options. These are Bermuda options, whose contract allows exercise usually on a few specific days before the expiration of an option. During these days, the buyer is allowed to buy, or the seller to sell, the underlying asset of his option. These days are very close to the expiration date of an option. That position gives more flexibility for traders to exercise their options compared to European options, but it is less flexible compared to American options.

One of the main solutions for overcoming the foreign exchange currency risk is to engage in forward stock or OTC market transactions. The use of forward contracts, swaps, FX futures, and options provides greater security and protection for participants in foreign trade transactions and thus motivates their more dynamic involvement in international trade.

⁴⁶⁸ Corporate Finance Institute, American vs European vs Bermudan Options, <https://corporatefinanceinstitute.com/resources/derivatives/american-vs-european-vs-bermudan-options/> (11.04.2025)

Chapter 16.

MODELS FOR ASSESSING THE FINANCIAL STABILITY OF INSURANCE COMPANIES

The efficient functioning of the insurance market requires financially reliable insurers, able to fulfil their obligations to policyholders on time and in full. The financial stability of insurers is the starting point for the continued implementation of the insurance function. The frequency and variety of risk manifestation models necessitate thorough risk analysis to justify the adoption of financial strategies by insurance companies. The application of economic-mathematical models provides a reliable basis for assessing the financial stability of insurers. To achieve financial stability, insurance companies engage in mathematical modelling of key indicators such as the probability of bankruptcy and the solvency margin.

Modelling the probability of bankruptcy in insurance companies serves as a tool for preventing insolvency. Accordingly, determining an adequate insurance premium is based on a previously estimated probability of bankruptcy. Differences between models arise from assumptions regarding the distribution, amount, and timing of insurance claim payments, which form the basis for their construction. Insurance claim payments are modelled using an appropriate probability distribution. The time intervals between claim payments are typically modelled using exponential distributions, while the sequence of claim events is defined by a Poisson process.

Assessing the financial stability of an insurance company is a complex process due to the multifaceted nature of the issue. The use of economic-mathematical models provides a foundation for generating valuable insights in the management decision-making process. From a market perspective, insurance companies aim to achieve the most reliable assessments of financial stability. However, this assessment is highly complex, and existing mathematical models often fail to incorporate all external factors that affect the financial soundness of insurance companies. Including a large number of variables results in a highly complex model that requires sophisticated solutions but yields more precise results. Conversely, simplifying the model by excluding certain factors facilitates easier computation but reduces the accuracy of the outcome.

Many factors affecting financial stability are difficult to express through explicit analytical relationships, which necessitates the use of approximate or simulation-

based models. The aforementioned models serve to assess the financial stability of companies, though they remain subject to the previously mentioned limitations in their development. Their application significantly enhances the validity of management decision-making and supports the financial stability of the company, based on indicators such as the probability of bankruptcy, the amount of initial capital and technical reserves, the solvency margin, and others. The initial capital and technical reserves of insurance companies operating in the Republic of Serbia are regulated by the Law on Insurance and the regulations of the National Bank of Serbia (NBS). The financial performance of insurance companies is published in NBS reports, which serve as one of the criteria for ranking and selecting companies within the insurance market.

Initial capital represents the minimum amount of a company's core capital, the required levels of which are prescribed by the Insurance Law depending on the type of insurance activity performed.⁴⁶⁹ Insurance companies are obliged to form technical reserves to ensure the fulfilment of contractual obligations toward policyholders. The company's technical reserves include:

- *Outstanding claims reserves*, which refer to claims that have occurred and for which the insurer is liable, but that have not been settled as of the balance sheet date.
- *Premium reserves*, representing the portion of the premium allocated to cover future risks during the insurance period.
- *Mathematical reserves*, applicable to life insurance, which represent the present value of future obligations arising from concluded contracts.
- *Reserves for claims oscillation*, intended to cover unexpected fluctuations in claims.
- *Other technical reserves*, formed based on the current balance sheet and prescribed in accordance with the regulations of the National Bank of Serbia (NBS).

Technical reserves must be adequately backed by the company's assets to ensure both solvency and liquidity. The National Bank of Serbia oversees the formation of technical reserves in order to protect policyholders and maintain stability in the insurance market.

The financial stability of an insurance company is analysed using two models: the first is based on risk analysis through a static approach, while the second uses a dynamic approach. In the static approach, time dependencies are not

⁴⁶⁹ Law on Insurance, *Official Gazette of the Republic of Serbia*, No. 139/2014 and 44/2021.

considered, which affects the modelling of premium and claim payments. In contrast, the dynamic approach incorporates time as a variable, meaning that the payment of insurance premiums and settlement of claims is time-dependent.

Reserve adequacy refers to an assessment of whether the allocated funds are sufficient to ensure the company's solvency. This evaluation is performed using a probability model or a marginal probability model, which measures the likelihood of a particular variable occurring independently of others. Thus, reserve adequacy is assessed using probabilistic models that estimate the likelihood that collected premiums will be sufficient to cover total claims in the observed period. An advantage of this approach lies in the simplified estimation of distribution parameters for random variables associated with individual insurance risks. To assess overall portfolio risk, claim payments are compared to received premiums and established reserves.

1. EVALUATION OF ECONOMIC-MATHEMATICAL MODELS FOR INSURANCE RISK ANALYSIS

Risk model based on a static approach

The static approach to risk modelling assumes that the total amount of claim payments is the sum of individual insurance claims paid to separate policyholders, forming the insurer's portfolio. The total claim amount is modelled as the sum of random variables representing actual claim payments. A key criterion in selecting an insurance company is the ratio between the insurance premium and the insured sum⁴⁷⁰.

The static model considers the insurer's portfolio under the following assumptions:

- A set of insured risks is established at a single point in time.
- Insurance premiums are paid at the moment the portfolio is formed.
- The duration of all insurance contracts is identical.
- The conclusion of an insurance contract entitles the policyholder to potential indemnity.

⁴⁷⁰ Popović, Z., Backović, M., & Babić, S. (2016). Risk analysis in life insurance policy selection by applying optimization criteria. In: *Risk Management in the financial services sector*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 399-417.

The static model is used to calculate the probability of company bankruptcy under the following assumptions:

- A fixed and relatively short time horizon is considered.
- The number of the insurance contracts is known and fixed (NIC).
- Insurance premiums are paid upon contract conclusion (IP).
- Statistical characteristics of individual claim amounts are known (AIC).

The mathematical model describing the financial condition of the insurance company is:

$$IF = IIC + TAIP - TAIC . \quad (1)$$

Here, the symbol IF represents the insurance fund at the end of the contract period, while IIC denotes the initial capital of the insurance company. The insurance premium is assumed to be identical across all contracts and the total insurance premium denoted as $TAIP$ is calculated using the formula:

$$TAIP = IP * NIC .$$

If the premium amount varies across contracts, the following expression is applied:

$$TAIP = \sum_{i=1}^{NIC} IP_i ,$$

where IP is the premium paid by policyholders to the insurance company. The symbol $TAIC$ denotes the total claim amount under insurance contracts, calculated as:

$$TAIC = \sum_{i=1}^{NIC} AIC_i . \quad (2)$$

The following assumptions are made to develop the static model:

- The random variables $AIC_1, \dots, AIC_{NIC}$ are independent, meaning that risks are not simultaneously covered under multiple contracts.
- These variables are non-negative and predetermined.
- Policyholders are homogeneous, and the random variables $AIC_1, \dots, AIC_{NIC}$ are identically distributed.
- Not all contracts generate claims, so some of the random variables $AIC_1, \dots, AIC_{NIC}$ may equal zero.

For the mathematical model of the company's financial position in expression (1), the probability of bankruptcy is given by:

$$PB = P \left\{ \sum_{i=1}^{NIC} AIC_i - IIC - IP \cdot NIC \geq 0 \right\}. \quad (3)$$

This represents the probability that total claims will exceed the sum of initial capital and collected premiums.

Risk model based on a dynamic approach

A non-decreasing series of random variables $t_0 = 0 \leq t_1 \leq \dots, T$ is analysed through the development of a risk model based on a dynamic approach, which characterises the timing of premium payments and the occurrence of claims.

The mathematical model of the financial balance of an insurance company based on a dynamic approach is represented by the following expression:

$$IF(t) = IIC + TAIP(t) - TAIC(t), \quad (4)$$

where:

$TAIP(t) = \sum_{i=1}^{NIC(t)} IP_i$ - represents the total insurance premium at the beginning of period (t) , while the symbol $NIC(t)$ refers to the random process representing the number of insurance contracts in period (t) ;

$TAIC(t) = \sum_{i=1}^{NIC(t)} AIC_i(t)$ - represents the random process of the total amount of claims in a period (t) , while $AIC_i(t)$ is the number of claims related to the i -th individual insurance event occurring in period (t) .

In practice, insurance premiums are generally received more frequently than claims are paid out, and premium amounts are typically smaller than the amounts paid in claims. Insurance premiums follow a continuous deterministic process, characterised by a single parameter — the cash flow rate of premium payments (cr). Accordingly, the total premium amount in period (t) is calculated using the following expression:

$$TAIP(t) = cr \cdot t. \quad (5)$$

The financial balance of the insurance company based on expression (4) is restated as:

$$IF(t) = IIC + cr \cdot t - \sum_{i=1}^{NIC(t)} AIC_i(t). \quad (6)$$

The associated random process, referred to as the “risk process” in economic-mathematical research,⁴⁷¹ is defined as:

$$RP(t) = cr \cdot t - \sum_{i=1}^{NIC(t)} AIC_i(t). \quad (7)$$

The probability of bankruptcy within a given period t is more consistent with real-world conditions. For the model expressed in (6), the bankruptcy probability is defined as:

$$PB = P[\exists t_0 : 0 < t_0 < T, t_0 = \min \{t : IIC + RP(t) < 0\}]. \quad (8)$$

which represents the probability that the available funds of the insurance company during period t will not be sufficient to cover claims. The timing of claims arrivals is described through a non-decreasing series of random variables ($t_0 = 0 \leq t_1 \leq t_2 \dots, t_n$). The time interval between two successive claim events is defined by the following expression:

$$T_n = t_n - t_{n-p} \geq 0. \quad (9)$$

It is assumed that claim payments cannot occur simultaneously under multiple contracts, given the number of claims (nc) for the random process of the insurance contract $NIC(t)$ in the period (t). The distribution of claim amounts is defined as:

$$PD_{nc}(t) = P\{NIC(t) = nc\} = P\left\{\sum_{i=1}^{nc} T_i \leq t \leq \sum_{i=1}^{nc+1} T_i\right\}. \quad (10)$$

A renewal process is established by assuming that the random variables are independent and identically distributed, with a defined distribution function.

⁴⁷¹ Swishchuk, A., Zagst, R., & Zeller, G. (2021). Hawkes processes in insurance: Risk models, applications to empirical data, and optimal investment. *Insurance: Mathematics and Economics*, 101, pp. 107-124

For further model development, the following hypotheses are introduced:

- Insurance claim payments in two time intervals are independent.
- The random process of the number of insurance contracts $NIC(t)$ in the period (t) is defined as a process with stationary increments, and $NIC(t+1) - NIC(t)$ and $NIC(t+h) - NIC(t)$ follow the same distribution.
- In each short interval, only one claim request occurs (due to the assumption of stationary increments).
- There is an average number of claims $\lambda > 0$, representing the expected number of claims in each interval, based on stationary increments.

Assumption 1) implies that claim payments occur independently. This is a realistic assumption in practice, as the probability of simultaneous claim events is low. A typical example of a renewal process is the Poisson process. The associated random variable follows an exponential distribution with parameter $\lambda > 0$. Therefore, the distribution $NIC(t)$ has the following expression:

$$p_{nc}(t) = e^{-\lambda t} \cdot \frac{(\lambda \cdot t)^{nc}}{nc!}, \quad nc = 0, 1, 2, \dots \quad (11)$$

For the Poisson process, the following holds:

- 1) Expected value (mean): $E[NIC(t)] = \lambda \cdot t$, $\mu[NIC(t)] = \lambda \cdot t$,
- 2) Variance: $\sigma^2 = \lambda \cdot t$.

The probability distributions for the expected number of claims (nc) within a single time period is obtained by applying the Excel function POISSON.DIST.

Table 1. Poisson probability distributions

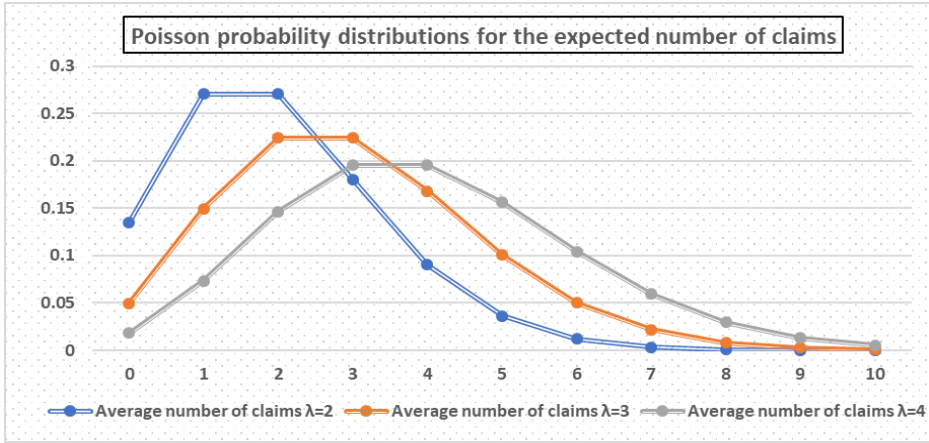
Expected number of claims	0	1	2	3	4	5	6	7	8	9	10
Average number of claims $\lambda=2$	0.13	0.27	0.27	0.18	0.09	0.03	0.01	0.003	0.0009	0.0002	4E-05
Average number of claims $\lambda=3$	0.04	0.14	0.22	0.22	0.16	0.10	0.05	0.02	0.008	0.002	8E-04
Average number of claims $\lambda=4$	0.01	0.07	0.14	0.19	0.19	0.15	0.10	0.05	0.02	0.01	0.005

Source: Author's calculation

Claim amounts are considered random variables and play a central role in risk assessment. A delay between submitting a claim and its settlement is

acknowledged; however, the model assumes that claims are paid at the time they are submitted.

Figure 1. Poisson probability distributions



Source: Author's illustration

The claim payment distribution function is defined as:

$$FDPD_{TAIC(t)}(taic) = P\{TAIC(t) \leq taic\} = P\left\{\sum_{i=1}^{NIC(t)} AIC_i \leq taic\right\}. \quad (12)$$

The assumptions that $\{AIC_i\}$ and $NIC(t)$ are independent random processes are introduced to apply the damage payment distribution function $FDPD_{TAIC(t)}(taic)$. While these assumptions are theoretical, they may not always hold in practice. Independence between processes $\{AIC_i\}$ and $NIC(t)$ is derived from the application of Poisson process. The distribution function for claims by individual insured events $FDPD_{TAIC(t)}(taic)$ (from expression (12)) is represented by the following expression:

$$FDPD_{TAIC(t)}(taic) = P\{TAIC(t) \leq taic\} = \sum_{nc=1}^{\infty} p_{nc}(t) \cdot FDPD_{AIC}^{nc}(taic). \quad (13)$$

Based on expressions (7) and (8), the claim distribution function is applied to evaluate the company's financial stability and is expressed as:

$$FDPD_{AIC}^{nc}(taic) = P\{AIC_1 + AIC_2 + \dots + AIC_{nc} \leq taic\}. \quad (14)$$

From an economic perspective, financial stability in insurance companies assumes that claim payments should not deplete available capital. It is essential that the remaining balance of the initial reserve, together with collected premiums, is sufficient to cover all future claims.

2. MATHEMATICAL METHODS AND PRINCIPLES OF CALCULATING INSURANCE PREMIUMS

The insurance premium represents the amount paid by the policyholder to the insurer, either as a lump sum or in instalments, in exchange for coverage against unforeseen events. The process of determining insurance premiums involves assessing the probability and potential impact of insured risks and defining an appropriate compensation function to cover possible losses.

Insurance premiums collected during a given period (t) should, in principle, be sufficient to cover the total claims incurred during that period $TAIC(t)$ - ideally exceeding or at least equalling the expected value of claims. However, theoretical and practical considerations suggest that the determination of insurance premiums is based on several guiding principles. These principles are generally classified into three methodological approaches: the ad-hoc method, the characterisation method, and the economic method.

Some common properties of insurance premium principles include the following:

- *Independence*: A premium principle satisfies the independence property if the distribution function of claim payments $FDPD[TAIC(t)]$ depends solely on the random process of claim amounts $TAIC(t)$ in period (t).
- *Burden of risk*: If the inequality $FDPD[TAIC(t)] \geq E[TAIC(t)]$ holds, the premium principle imposes an unjustified burden of risk. Conversely, if equality applies for all constant risks, the principle is considered not to impose such a burden.
- *Invariance*: This includes both scale invariance and translational invariance. Scale invariance is satisfied if:

$$FDPD[con \cdot TAIC(t)] = con \cdot FDPD[TAIC(t)],$$
and translational invariance holds if:

$$FDPD[con + TAIC(t)] = con + FDPD[TAIC(t)].$$
- *Additivity*: A principle is additive if it satisfies:

$$FDPD[TAIC(t_1) + TAIC(t_2)] = FDPD[TAIC(t_1)] + FDPD[TAIC(t_2)].$$
It is sub-additive if:

$$FDPD[TAIC(t_1) + TAIC(t_2)] \leq FDPD[TAIC(t_1)] + FDPD[TAIC(t_2)].$$

It is super-additive if:

$$FDPD[TAIC(t_1) + TAIC(t_2)] \leq FDPD[TAIC(t_1)] + FDPD[TAIC(t_2)].$$

One of the key parameters that determines the financial stability of an insurance company is its tariff structure. The tariff rate represents the price of insurance coverage for uncertain future liabilities⁴⁷². This concept is discussed in detail by Kočović et al. (2021). The insurance premium serves multiple functions for insurance companies. It guarantees the payment of future claims and also acts as a benchmark for competition in the insurance market. The ratio between the insurance premium and the insured amount is often used as a criterion for selecting an insurer⁴⁷³. The premium calculation method is based on the company's available statistical data. The insurance premium $TAIP(t)$ in the time interval $[t]$ is calculated using the following expression:

$$TAIP(t) = (1 + fl) \cdot [E[NIC(t)] - E[TAIC(t)]] \quad (15)$$

where the term (fl) denotes a constant called the *load factor*. It is assumed that the variable $TAIC(t)$ follows the same distribution as each $AIC_i(t)$, which represents the random process of the number of claims related to each insurance case in period (t) .

The structure of the insurance premium is based on the principle of equivalence in the relationship between the insurer and the policyholder, as well as on the need to maintain the financial stability of the insurance company. Formula (15) implies that the average insurance premium amounts should exceed the total cumulative value of claim payments during period (t) .

Adequate insurance premiums are calculated by constructing a process denoted as $TAIP(t)$, based on the distribution function of claim payments. Accordingly, the key characteristics of the random process representing the total amount of claims $TAIC(t)$ — namely, the mathematical expectation and variance — are used in determining the insurance premium for the claims incurred during period (t) . The estimated risk has a significant impact on the insurance premium, as its amount depends on the probability and severity of potential losses, represented

⁴⁷² Kočović, J., Rakonjac-Antić, T., Koprivica, M., & Šulejić, P. (2021). *Osiguranje u teoriji i praksi*, Belgrade: University of Belgrade, Faculty of Economics and Business.

⁴⁷³ Popović et al. (2016), op. cit.

by the risk measures $TAIP[TAIC(t)]$ or $TAIP[FDPD_{TAIC(t)}]$. The symbol $FDPD_{TAIC(t)}$ denotes the distribution function of claim amounts.

The general properties of the insurance premium function $TAIP[TAIC(t)]$ are defined by the following expressions:

- $TAIP(con) = con$ - for any constant con , when no load factor is applied,
- $TAIP[con \cdot TAIC(t)] = con \cdot TAIP[TAIC(t)]$ - for any constant con ,
- $TAIP[TAIC(t) + con] = TAIP[TAIC(t)] + con$ - for any constant con ,
- $TAIP[TAIC_1(t) + TAIC_2(t)] < TAIP[TAIC_1(t)] + TAIP[TAIC_2(t)]$,
- $TAIC_1(t) < TAIC_2(t) \Rightarrow TAIP[TAIC_1(t)] < TAIP[TAIC_2(t)]$.

The basic actuarial principles for forming the insurance premium are expressed through the following expressions:

- Expected value principle

$$TAIP[TAIC(t)] = (1 + con) \cdot E[TAIC(t)], con > 0.$$

- Variance (dispersion) principle

$$TAIP[TAIC(t)] = E[TAIC(t)] + con \cdot Var[TAIC(t)].$$

- Standard deviation principle

$$TAIP[TAIC(t)] = E[TAIC(t)] + con \cdot \sqrt{Var[TAIC(t)]}.$$

- Exponential utility principle

$$TAIP[TAIC(t)] = \frac{1}{con} \cdot \log E[e^{con \cdot TAIC(t)}].$$

- Absolute deviation principle

$$TAIP[TAIC(t)] = E[TAIC(t)] + con \cdot k_{TAIC(t)}.$$

- Equivalent utility (zero utility) principle

$$u(0) = E[u(TAIP(TAIC(t)) - TAIC(t))].$$

The risk model analysis is applied to a company whose portfolio consists of insurance contracts $NIC(t)$, with incurred claim payments denoted by $AIC_i(t)$, which are independent and represent a random process for the total amount of claims related to individual insurance events over a specified time period (t) . The random process of total claims during period (t) is expressed as:

$$TAIC(t) = \sum_{i=1}^{NIC(t)} AIC_i(t), \text{ where } TAIC(t) \text{ follows a claim distribution function}$$

given by: $FDPD_{AIC}^{nc}(taic) = P\{AIC_1 + AIC_2 + \dots + AIC_{nc} \leq taic\}$.

The initial assumption implies that the insurance company concludes insurance contracts for a limited period. Each contract covers only one claim event, meaning that multiple claims are not settled under a single insurance contract. The payment for an individual claim is represented by a random variable $AIC_i(t)$ whose value may be equal to zero. Based on these assumptions, the total claim payment at the end of the insurance contract period is given by the following expression: $TAIC(t) = \sum_{i=1}^{NIC(t)} AIC_i(t)$.

The probability of bankruptcy of an insurance company is calculated as $PB\{TAIC(t) > IIC + TAIP(t)\}$, i.e., the probability that the total amount of claim payments exceeds the sum of the initial capital and collected insurance premiums.

The Poisson process is traditionally based on the assumption that all insurance claim amounts are identical. However, in practice, claim amounts vary significantly. Consequently, instead of assuming fixed claim amounts, we incorporate randomly distributed claim values, resulting in a more complex version of the Poisson process.⁴⁷⁴ If the random variable representing claim size is not exponentially distributed with parameter $\lambda > 0$, the analytical tractability of the model is lost, and closed-form results become difficult to obtain, demonstrating a key limitation of the standard Poisson process. To estimate the number of claims and assess potential insolvency, approximate results can be derived using the Central Limit Theorem. These approximations serve as useful tools in calculating the probability of an insurance company's bankruptcy.

The probability of bankruptcy is calculated with considerable technical complexity, often requiring approximation methods based on the Central Limit Theorem. The insurance premium is defined as the price of insurance (the price

⁴⁷⁴ Challa, A. (2012). *Insurance models and risk-function premium principle*. University of Warwick, pp. 1-23.

of risk), and is used to determine the amount payable by the policyholder.⁴⁷⁵ The total insurance premium consists of the net premium and the overhead allowance. The net premium itself is composed of two components: the technical premium and the preventive allowance. The technical premium must be sufficient to cover claims arising under the insurance policy, while the preventive allowance is allocated for activities aimed at reducing and preventing insured losses.

The principle of net insurance premium is defined by the following expression:

$$TAIP(t) = E[TAIC(t)]. \quad (16)$$

The probability of company bankruptcy is given by the equation:

$$\begin{aligned} PB\{TAIC(t) > TAIP(t)\} &= PB\{TAIC(t) - E[TAIC(t)] > 0\} = \\ &= PB\left\{\frac{TAIC(t) - E[TAIC(t)]}{\sqrt{Var[TAIC(t)]}} > 0\right\} \approx 0.5 \end{aligned} \quad (17)$$

In this case, the net premium principle is considered inadequate. The main reason lies in the inability of this principle to ensure the financial stability of the insurance company, particularly with respect to the unacceptable level of bankruptcy risk.

The rationale for introducing a risk premium lies in the necessity to meet the insurer's financial stability requirements. Specifically, the total premium charged by the company should be sufficient to cover incurred claims with a probability that approaches 1.

Based on the standard deviation principle, the insurance premium is determined according to the following expression:

$$TAIP[TAIC(t)] = E[TAIC(t)] + con \cdot \sqrt{Var[TAIC(t)]}. \quad (18)$$

The probability of a company's bankruptcy is calculated using the following expression:

$$PB\{TAIC(t) > TAIP(t)\} = PB\left\{\frac{TAIC(t) - E[TAIC(t)]}{\sqrt{Var[TAIC(t)]}} > con\right\} \approx 1 - F(con). \quad (19)$$

⁴⁷⁵ Kočović et al. (2021), op. cit.

To determine a fixed level of risk (frl), reference tables are used to identify the parameter con^* such that $F(con^*) = 1 - \varepsilon$. It is assumed that this value $con = con^*$ determines the insurance premium with a loading component that ensures the probability of bankruptcy does not exceed the specified threshold. This is expressed as:

$$PB\{TAIC(t) > TAIP(t)\} \approx \varepsilon. \quad (20)$$

From this equation, it follows that determining the appropriate net insurance premium is an inverse problem relative to the condition of financial stability—in other words, it represents the inverse problem of avoiding bankruptcy.

The Poisson process is used to model the probability distribution of the number of expected claims (nc) given an average claim frequency (λ) during a specified period (t). The calculated claim amounts serve as key inputs in evaluating the insurer's risk exposure. By applying the Poisson distribution and expression (20), the probability of bankruptcy for the insurance company can be assessed. A hypothetical example is provided in Table 1. If, during a given period $t = 1$, the average number of claims is $\lambda = 3$, then the insurer expects the fixed risk level to be realized at a claim count of $nc = 6$. In such a case, the insurance premium, including the load factor that ensures the probability of bankruptcy defined by expression (20), is calculated using the following formula:

$$PB\{TAIC(t) > TAIP(t)\} = 0.05041.$$

3. METHOD FOR CALCULATING BANKRUPTCY RISKS OF INSURANCE COMPANIES

It is assumed that there is an unknown number of insurance contracts $NIC(t)$ in a given time period (t), under which claim payments are made. Accordingly, two fundamentally different modelling approaches are considered: a static model and a dynamic model. In the static approach, claim payments are made at the end of the contract period and are independent of time (t). This corresponds to modelling with an integer-valued random variable NIC that remains fixed throughout the period.

In contrast, under dynamic approach $NIC(t)$ represent a random process in which claim payments are made during the contract period (t). Each claim amount is positive and independent of the total number of contracts. The exact timing of claim events is unknown—a feature that reflects actual conditions in

the insurance market. This approach allows for greater flexibility and responsiveness in risk management.

To assess the company's bankruptcy risk, the following expression is applied:

$$TAIC(t) = \sum_{i=1}^{NIC(t)} AIC_i(t). \quad (21)$$

Claims are modelled by a Poisson process with intensity λ . Claim amounts $AIC_i(t)$ are independent and identically distributed random variables, independent of the number of claims. Insurance premiums accumulated up to a certain point in time (t), denoted by $TAIP(t) = \sum_{i=1}^{NIC(t)} IP_i$ are a linear function of time, as previously defined in expression (5). The risk process $TAIC(t) = \sum_{i=1}^{NIC(t)} AIC_i(t)$, in this case corresponds to a compound Poisson process. For further details on compound Poisson processes, see Finan (2017)⁴⁷⁶ and Challa (2012).

The insurer receives premiums from policyholders at an intensity (cr), where (cr) represents the positive premium cash flow rate. The initial capital is denoted by IIC . In the risk process defined by expression (21), the number of insurance contracts and the amount of damage per claim are treated as independent random variables. The expected value of claim amounts in period (t), denoted by $acoc_i$ is defined as:

$$\mu[TAIC(t)] = \lambda \cdot t \cdot acoc_i. \quad (22)$$

Since premiums accumulate over time, $TAIP(t) = cr \cdot t$ is a linear function of time and the arithmetic mean of the total claims in the period (t), given by the expression (22), serves as the basis for determining the load factor (β).

⁴⁷⁶ Finan, M. A. (2017). An introductory guide in the construction of actuarial models: a preparation for the actuarial exam. *Actuarial Exam C/4*. Russellville, AR: Arkansas Tech University, <http://faculty.atu.edu/mfinan/actuariesshall/CGUIDE.pdf> (accessed 11.2.2018).

$$fl = \frac{TAIP(t)}{\mu[TAIC(t)]} = \frac{cr \cdot t}{\lambda \cdot t \cdot acoc_i}, \quad (23)$$

$$fl = \frac{cr \cdot t}{\lambda \cdot t \cdot acoc_i}. \quad (23a)$$

From equation (23a), the premium cash flow rate, or insurance premium rate, is expressed as:

$$cr = \lambda \cdot acoc_i \cdot fl. \quad (24)$$

The load factor given by (23a) represents the ratio between the excess premium rate and the claim payment rate for insured events.

The determination of the load factor based on empirical data and the calculation of the correction coefficient depend on the insurer's initial capital, as incorporated into expression (24). Based on this, both the lower and upper bounds for the probability of bankruptcy can be established. As an illustrative example, base values are assumed for the average number of claims λ in the period t . The load factor is then calculated according to the expected number of claims and the associated Poisson probability distribution.

In the illustrative example, it is assumed that the average claim amount is 5,000 RSD. The assumption is that the insurance company opts for a safety load of 20%. The safety load accounts for uncertainty in risk assessment, administrative costs, and the insurer's profit margin. The procedure for determining the load factor is based on the following steps:

- Base net premium = average number of claims * average claim amount
- Base gross premium = base net premium * (1 + safety load)
- Gross premium for expected number of claims = base gross premium + expected number of claims * (1 + safety load) * Poisson probability
- Load factor = gross premium for the expected number of claims / base gross premium

Table 2. Assumed values for a hypothetical example

Average number of claims $\lambda=3$ in period (t)	
Average claim amount	5,000.00
Safety load (Load factor)	20%

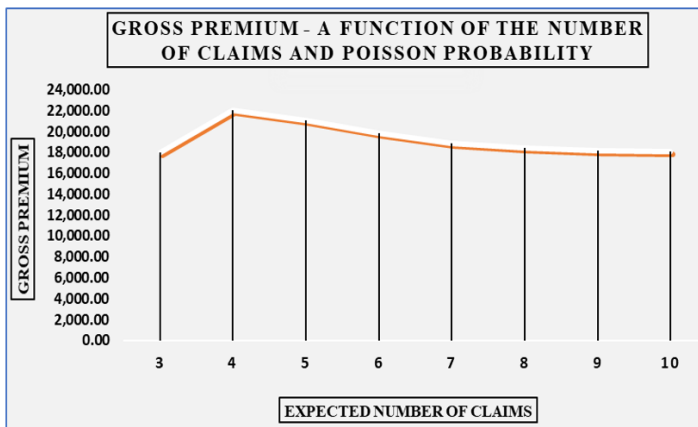
Source: Author's assumptions

Table 3. Calculated results for a hypothetical example

Expected number of claims	Net premium	Premium with safety load	Poisson's probabilities	Gross premium	Load factor	Load factor (%)
3	15,000.00	18,000.00		18,000.00		0.00%
4			0.16803136	22,032.75	1.2240	22.40%
5			0.10081881	21,024.56	1.1680	16.80%
6			0.05040941	19,814.74	1.1008	10.08%
7			0.02160403	18,907.37	1.0504	5.04%
8			0.00810151	18,388.87	1.0216	2.16%
9			0.0027005	18,145.83	1.0081	0.81%
10			0.00081015	18,048.61	1.0027	0.27%

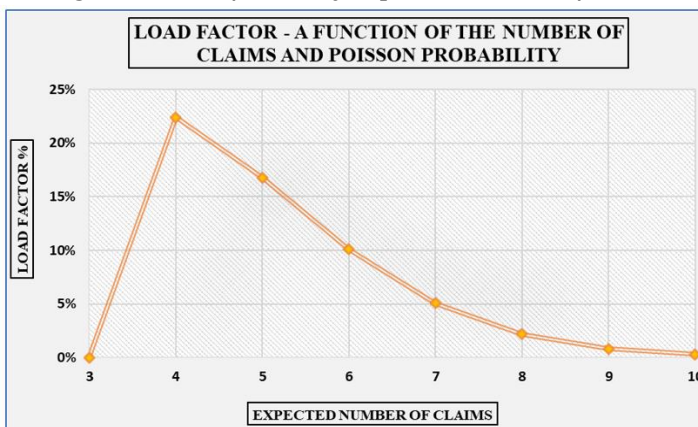
Source: Author's calculation

Figure 2. Gross premiums by expected number of claims



Source: Author's illustration

Figure 3. Load factors by expected number of claims



Source: Author's illustration

Based on the initial assumptions—average number of claims $\lambda = 3$, average claim amount of 5,000 RSD and a safety load of 20%, the following conclusions are drawn:

- As the expected number of claims increases relative to the average claim amount, the Poisson probability of incurred claims decreases and tends toward zero. Consequently, the gross premium approaches the base gross premium;
- Likewise, the load factor gradually converges toward the safety load value. This confirms that the chosen safety load is sufficient to maintain the insurer's liquidity.

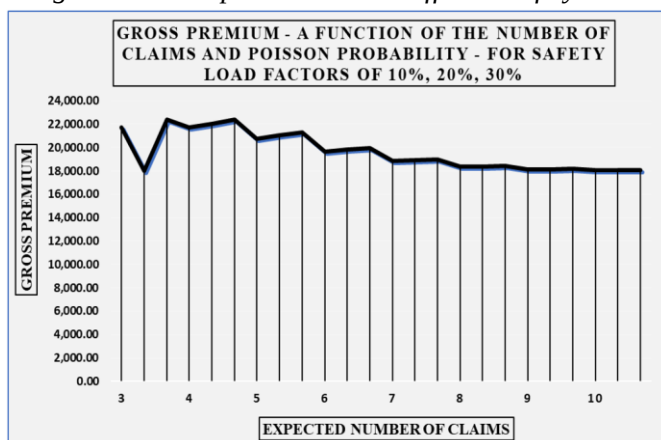
A sensitivity test was performed by varying the safety load at 10%, 20%, and 30%, while keeping all other parameters constant.

Table 4. Calculated results with varying safety loads

Expected number of claims	Safety load	Net premium	Premium with safety load	Poisson's probab.	Gross premium	Load Factor	Load Factor (%)
3	10%	15000	16,500.00	0.22404	21,696.6	1.2053	20.54%
	20%	15000	18,000.00	0.22404	18,000.0	1	0.00%
	30%	15000	19,500.00	0.22404	22,368.8	1.2427	24.27%
4	10%	20000	22,000.00	0.16803	21,696.6	1.2053	20.54%
	20%	20000	24,000.00	0.16803	22,032.7	1.2240	22.40%
	30%	20000	26,000.00	0.16803	22,368.8	1.2427	24.27%
5	10%	25000	27,500.00	0.10081	20,772.5	1.1540	15.40%
	20%	25000	30,000.00	0.10081	21,024.5	1.1680	16.80%
	30%	25000	32,500.00	0.10081	21,276.6	1.1820	18.20%
6	10%	30000	33,000.00	0.05040	19,663.5	1.0924	9.24%
	20%	30000	36,000.00	0.05040	19,814.7	1.1008	10.08%
	30%	30000	39,000.00	0.05040	19,965.9	1.1092	10.92%
7	10%	35000	38,500.00	0.02160	18,831.7	1.0462	4.62%
	20%	35000	42,000.00	0.02160	18,907.3	1.0504	5.04%
	30%	35000	45,500.00	0.02160	18,982.9	1.0546	5.46%
8	10%	40000	44,000.00	0.00810	18,356.4	1.0198	1.98%
	20%	40000	48,000.00	0.00810	18,388.8	1.0216	2.16%
	30%	40000	52,000.00	0.00810	18,421.2	1.0234	2.34%
9	10%	45000	49,500.00	0.00270	18,133.6	1.0074	0.74%
	20%	45000	54,000.00	0.00270	18,145.8	1.0081	0.81%
	30%	45000	58,500.00	0.00270	18,157.9	1.0087	0.88%
10	10%	50000	55,000.00	0.00081	18,044.5	1.0024	0.25%
	20%	50000	60,000.00	0.00081	18,048.6	1.0027	0.27%
	30%	50000	65,000.00	0.00081	18,052.6	1.0029	0.00%

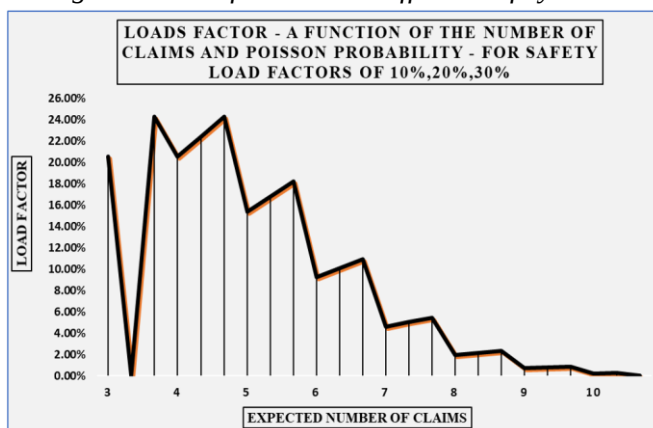
Source: Author's calculation

Figure 4. Gross premiums with different safety loads



Source: Author's illustration

Figure 5. Load factors with different safety loads



Source: Author's illustration

* * *

Based on the results obtained for the application of a load factor of 10% or 30%, under the assumed base conditions - the average number of claims λ , the average amount of claims of 5,000 RSD and the safety load of 20%, the following conclusions are drawn:

- For $\lambda = 3$, changing the safety load to 10% or 30% results in load factor values that differ from the baseline (20%) by between 0.54% and 4.27%.

- For $\lambda = 4$, a safety load of 20% increases the load factor by 2.4%. Changes to 10% or 30% again yield a variation in load factor within the range of 0.54% to 4.27%.
- As the expected number of claims increases, the load factor converges toward the safety load, confirming that the selected safety load ensures the insurer's liquidity.
- With an average of 3 claims and a base gross premium of 18,000 RSD, changing the safety load from 10% to 30% increases gross premium amounts by RSD 3,696.69 to RSD 4,368.82.
- For an expected number of 4 claims, the gross premium increases by RSD 4,032.75 under a 20% safety load. Adjustments to 10% or 30% change the gross premium within the same interval (RSD 3,696.69 to RSD 4,368.82).
- An increase in the expected number of claims leads to a decrease in the gross premium value. With further increases, the gross premium approaches the base gross premium.

The research conclusions are derived from the development of a dynamic process-based model. Specifically, the model analyses the relationship between premium inflows from concluded insurance contracts and claim outflows related to all contracts entered into by the insurer on the insurance market. Within this framework, the model primarily evaluates the insurer's financial stability over a defined time horizon.

Based on the developed model, it is concluded that a key determinant of insurers' financial stability is the correlation between received insurance premiums and claims paid for insured events. This correlation reflects several underlying factors: the rate of premium collection, the frequency and timing of claim payments, and the statistical distribution of incurred claims.

The model's key limitations arise from how financial stability is defined. These conditions are considered sufficient when collected premiums are equal to the funds available for claim settlements during the observed period. Additional limitations relate to the current treatment of risks across different insurance contracts. A more comprehensive analysis of diverse risk types is essential for improving model accuracy and reinforcing financial resilience. Future research should aim to include multiple, or ideally all, types of risks in assessing the financial stability of insurance companies operating in the market

SMART COLLECTIVE BARGAINING IN FINANCIAL SERVICES IN SERBIA

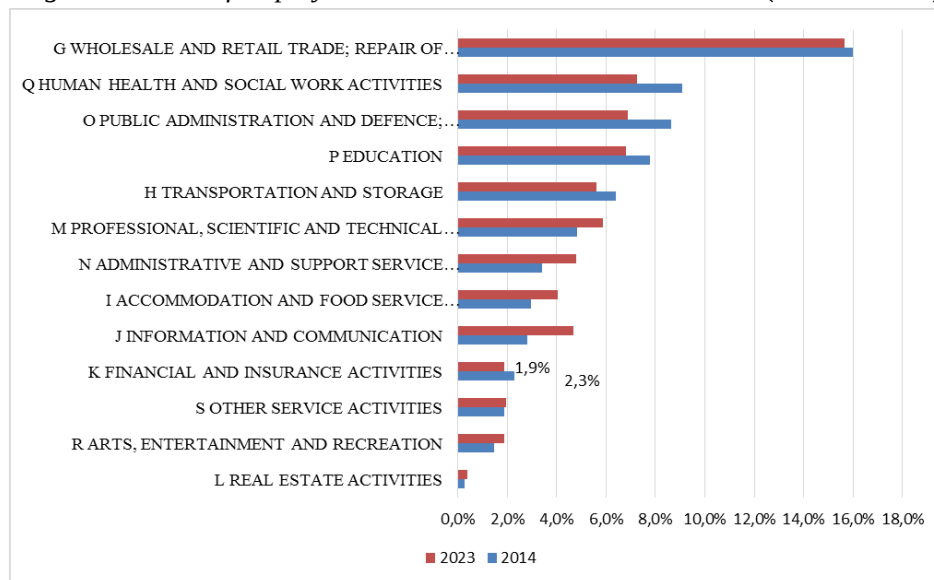
While the most developed EU countries, particularly Germany and the Nordic countries, are characterised by strong unions and large bargaining coverage in both the industry and services sectors, protection of collective rights in Serbia, as a candidate country, is still lagging behind. In spite of the long tradition of unionisation, primarily in industry, union density in Serbia has substantially decreased over time. The current situation in collective bargaining in Serbia is characterised by relatively strong unions and large bargaining coverage in the public sector, followed by large private sector companies, however, mainly operating in the manufacturing industry. Against such a backdrop, it is interesting to analyse the current state and possibilities for further development of collective bargaining in the growing services sector in Serbia. This chapter thus focuses on financial services, whose share in the total employment in Serbia is rather small (around 2%), yet is dominated by private companies, many of which include large international market players providing banking and insurance services. The two biggest sub-sectors in financial services in Serbia include NACE 64 (financial service activities, except insurance and pension funding) and NACE 65 (Insurance, reinsurance and pension funding, except compulsory social security). Taken together, these two sub-sectors in 2023 employed as many as 86% of all registered employees in financial services. Thus, the aim of this chapter is to compare the current state of collective bargaining between the two, as well as to discuss the potential for implementing the novel idea of smart collective bargaining. The proposed new approach in collective bargaining should better fit the needs of both parties (employers and employees) in the changing working environment affected by innovative practices such as digitalisation and innovative work arrangements.

1. EMPLOYMENT TRENDS IN A CHANGING BUSINESS ENVIRONMENT

The financial services sector in Serbia is relatively small, taking into consideration the total number of employed as well as its share in the total employment. Namely, according to CROSO, in 2023 registered employment in the financial sector was 43,680, while its share in total employment was 1.9%. In comparison with 2014, the total employment increased from 42,062, yet the share in the total employment decreased from 2,3%, as shown on Figure 1 bellow. Also,

Figure 1 clearly shows that taking its share of employment, the financial sector has remained among the smallest sectors in services in Serbia.

Figure 1. Share of employment in subsectors in 2014 and 2023 (CROSO, 15+)



Source: CROSO, authors' calculation

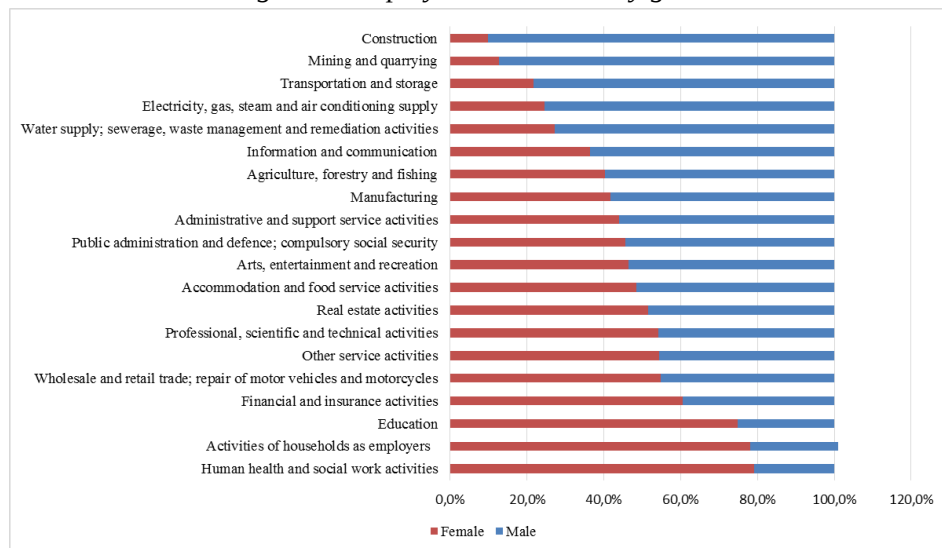
With a virtually non-existent stock market, most workers are employed in private companies, including insurance companies (20), pension funds (4), commercial banks (19), as well as other financial institutions (e.g. payment service providers, electronic money institutions, etc.)⁴⁷⁷. As already noted above, over the last decade, registered employment in the sector increased by 1,618 employees, yet its share in total employment decreased. Along with CROSO, it is worth mentioning that LFS data show slightly higher employment in financial services in 2023 (51,100 workers), and a similar share in total employment (1.8%). Female workers dominate, accounting for 60.5% of all workers in financial services. Moreover, as shown in Figure 2, together with human health and social services as well as education, financial services represent one of the four sectors in which female workers are the majority.

What is particularly important, especially for understanding the need and the solid ground for initiating and nurturing smart collective bargaining, is that informal employment in the services sector is generally lower than for the economy. Informal employment in financial services is the second lowest in the

⁴⁷⁷ Data available from: https://www.nbs.rs/sr_RS/indeks/

services sector (after human health and social work activities), with the informal rate of 1.3% in 2020 (LFS).

Figure 2. Employment structure by gender



Source: LFS, authors' calculation

In this chapter, we focus on the two biggest sub-sectors in financial services in Serbia, including NACE 64 (financial service activities, except insurance and pension funding) and NACE 65 (Insurance, reinsurance and pension funding, except compulsory social security). Taken together, these two sub-sectors in 2023 employed as many as 86% of all registered employees in financial services (see Table 1). Thus, our aim is to compare the current state of collective bargaining between the two, as well as to discuss the potential for implementing the novel idea of smart collective bargaining. The proposed innovative approach of collective bargaining (smart collective bargaining) should better fit the needs of both parties (employers and employees) in the changing working environment affected by innovative practices such as digitalisation and innovative work arrangements.

NACE 64 (financial service activities, except insurance and pension funding) has remained the single biggest sub-sector, accounting for more than 50% of registered employment. With 26,538 registered employees in 2023, NACE 64 accounted for 1% of the total employment. However, over the last decade the number of employed in this sub-sector was shrinking, as well as its share in the total employment, from 2% in 2014 to 1% in 2023. On the other hand, by the total number of registered employment NACE 65 (Insurance, reinsurance and

pension funding, except compulsory social security) has remained substantially smaller. However, unlike NACE 64 whose share in the total employment over the last decade has been shrinking, in NACE 65 it has remained rather stable, along with the growing number of employed in insurance companies and pension funds. Detailed data are presented in the Table 1.

Table 1. Registered employment in financial services, NACE 64 and NACE 65

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Registered employment										
Total employment	1,845,494	1,896,295	1,920,679	1,977,357	2,052,546	2,101,267	2,149,099	2,212,631	2,253,473	2,306,955
Financial Sector	42,062	45,806	44,524	43,746	43,774	43,849	43,736	42,889	42,297	43,680
Share in total employemnt	2,3%	2,4%	2,3%	2,2%	2,1%	2,1%	2,0%	1,9%	1,9%	1,9%
NACE 64	28,801	29,767	28,754	28,091	27,97	27,752	27,213	26,121	25,544	26,538
Share in total employemnt	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%
NACE 65	8,900	10,883	10,712	10,510	10,333	10,461	10,782	10,950	10,844	10,970
Share in total employemnt	0,48%	0,57%	0,56%	0,53%	0,50%	0,50%	0,50%	0,49%	0,48%	0,48%

Source: CROSO, authors' calculation

Private companies dominate in financial services as a whole and NACE 64 in particular. According to available data, there are 19 registered banks, including 18 private banks, most of which are affiliated with foreign companies, and 2 domestic banks owned by the Republic of Serbia. The number of commercial banks has substantially decreased, due to the high concentration of capital in the banking sector. Other financial institutions include payment service providers (8), electronic money institutions (7), as well as a number of retailers, including exchange offices and smaller affiliated payment service providers. In a similar manner, private companies (joint-stock) also dominate in NACE 65 (16 insurance companies, 4 reinsurance and 4 pension funds). In one case (Dunav osiguranje), the Government of Serbia has remained the majority shareholder holding 76,7% of the total capital. This particular company is further presented as a case study with a relatively strong trade union and negotiated collective bargaining agreement (CBA), which is typical for public companies in Serbia.

Digitalisation of financial services has developed substantially over the last couple of years, thus opening space for reducing personal contacts with clients and downsizing of professional staff in banks, insurance companies, pension funds, as well as other financial institutions. However, in the same period, the labour supply in Serbia has been shrinking, whereas recruitment and employment of highly competent workers for technologically more sophisticated jobs has brought another important challenge. In some cases, due to digital transformation, it was necessary to develop training programs to improve the skills of their

personnel in distance (i.e. digital) counselling as well as to develop programs for further improvement of managerial competences.

In light of significant ongoing technological transformations, collective bargaining in the financial sector and particularly in insurance companies and commercial banks should be analysed with great care, taking into consideration its potential to adequately and more precisely regulate work relations between employers and employees in a changing work environment.

2. SHORT HISTORY AND CURRENT STATE OF INDUSTRIAL RELATIONS IN SERBIA

Workers' organisations in Serbia have a long tradition dating back to the end of the 19th century and the Workers Confederation (Radnički savet), the first trade union confederation in Serbia, was established in 1903⁴⁷⁸. As the predecessor of the Confederation of Autonomous Trade Unions of Serbia (*CATUS, Savez samostalnih sindikata Srbije, SSSS*), this organisation was established upon a decision made by a number of professional and local worker organisations in the branches of construction, metal manufacturing, commerce and printing to associate into the first trade union confederation in Serbia.

The establishment of worker associations in Serbia is granted by the Constitution and further regulated in detail by the Labour Code. Worker associations may be established on various levels, including company, industry/sectoral, territorial, and national levels.

At present, several trade union confederations can be distinguished at the national level – the Confederation of Autonomous Trade Unions of Serbia (*CATUS, Savez samostalnih sindikata Srbije, SSSS*), the United Branch Trade Unions (*UGS Nezavisnost*), the Confederation of Free Trade Unions (*CFTU – Konfederacija slobodnih sindikata*) and the United Trade Unions of Serbia (*Sloga*). The first two are currently recognised as representatives at the national level, and as such, are eligible to participate in social dialogue as entitled members of the Socio-Economic Council (SEC). On the other hand, CFTU, though recognised as representative by the relevant Ministry in 2012⁴⁷⁹, it is not a member of either the Socio-Economic Council nor any other relevant tripartite body. Another

⁴⁷⁸ Pavlović, M., & Marković, P. (2013). *Od Radničkog saveza do Samostalnog sindikata Srbije: 1903-2013*. Belgrade: Union of Independent Trade Unions of Serbia, Institute for Contemporary History.

⁴⁷⁹ Solution No. 110-00-1269/2009-02 of 03.05.2012, *Official Gazette of the Republic of Serbia*, No. 55/12.

nationwide confederation, ASNS, lost its representativeness almost 20 years ago, and its membership and influence have been on a long-term decline. In addition to the listed union umbrella organisations, there are several smaller unions organised at the sectoral and company levels that do not belong to any headquarters.

Industrial relations in Serbia are regulated by the comprehensive body of labour legislation, including the cornerstone Labour Code, as well as the Law on Peaceful Settlement of Labour Disputes and The Rulebook on the Registration of Collective Agreements. Additionally, Serbia has ratified two fundamental international conventions of the International Labour Organization (ILO) covering the freedom of association, i.e. C087 – the Freedom of Association and Protection of the Right to Organise Convention and C098 – the Right to Organise and Collective Bargaining Convention.

After the democratic changes that facilitated the privatisation of former ‘socially-owned’ firms in the early 2000s, there has been a steady drop in trade union density. According to the latest available OECD data, the density decreased from 33.3% in 2010 to 26.4% in 2014. Currently, the local trade unions have reported around 500,000 members, which, taking the total registered employment (around 2,3 million), suggests that union density has decreased by around 22%. The adjusted bargaining coverage rate, which is a share of employees with the right to bargain, decreased even more from 55% in 2010 to 30% in 2019. The other side of the bargaining spectrum has similar coverage, with an employer organisation density of 25% in 2019⁴⁸⁰.

While the public sector continued to have a high (albeit declining) trade union density, the union density in the private corporate sector is very low. Ironically, the sharp decline in private dependent employment in the first decade of the millennium was the single element that significantly reduced this tendency. Consequently, the reduction of overall union density was accelerated with the expansion of private employment after the Recession. Some recovery in trade union membership in the private sector within the overall continuous declining trend could be ascribed to the expansion of foreign direct investment, since some foreign investors, especially from EU countries, have been more permissive toward worker organisations than their local counterparts.

According to the Labour Code, an employer association may be established provided that its members employ a minimum of 5% of employees in a particular

⁴⁸⁰ OECD & AIAS (2021). *International Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts*. Paris: OECD Publishing.

branch/sector/industry and/or territory. However, the interest of local employers in Serbia to form employer associations is weak or non-existent. Therefore, in many industries, collective bargaining on sectoral or territorial levels in Serbia is not possible due to the non-existence or non-representativeness of the relevant negotiating party on the side of employers. At present, there are four nationwide as well as five industry-level employer associations in Serbia⁴⁸¹.

The only representative association of employers in Serbia is the *Serbian Association of Employers* (SAE) (srb. *Unija poslodavaca Srbije*). Not only is SAE the sole nationally representative employer organisation, but in recent years, it has remained the only one recognised as a representative of the interests of employers at any level of social dialogue and an entitled member of the SEC.

In addition, all companies operating in Serbia are legally obliged to associate within the Serbian Chamber of Commerce (PKS). PKS offers diverse services to business entities mainly in regard to the improvement of their export potentials, international promotion and collaboration, as well as advocacy of various business and/or regulatory initiatives. However, these sectoral associations within PKS are mainly focused on the protection of business interests, whereas the issues regarding social dialogue and collective bargaining are out of the scope of their activities.

As presented above, while the density of trade unions has been declining, the number and coverage of employers' associations are rather limited, thus making social dialogue and collective bargaining difficult or even impossible in many instances. Representativeness of both workers' and employers' associations remains the primary constraint hindering possibilities for collective bargaining on any level. The criteria for representativeness of both industrial relations actors are defined by the Labour Code. In the case of trade unions, to be considered as a representative in bipartite social dialogue, at least 15% of company employees must be members of the trade union. The condition for representatives at the national level is somewhat relaxed, so to be nationally recognized, union membership must exceed 10% of total employment. On the employers' side, the legal requirement for representativeness at the national level is that an employer association unites at least 10% of all registered employers who employ at least 15% of the total number of workers in the country.

Collective bargaining in Serbia operates on all three levels (company, sectoral and national), but with varying importance. In line with it, three types of collective agreements are recognised in the Labour Code: 1) general, 2) sectoral

⁴⁸¹ Institute for Industrial Relations (2023), <http://www.iio.org.rs/employers>

collective agreement and 3) company-related collective agreement. The last general collective agreement in Serbia was concluded between SAE and two representative Trade Unions (CATUS and UGZ Nezavisnost) in April 2008. In accordance with the Law, in 2011, it became ineffective as the new general collective agreement had not been signed.

The national level of collective bargaining is the most important one from the macroeconomic standpoint. While a general collective agreement is still non-existent, negotiations on the minimum wage are fully centralised and binding for the entire economy. The national tripartite dialogue is institutionalized within the Social Economic Council (SEC). The SEC has 18 members, including six from the Government (representatives from the Ministry of Labour, Employment, Veteran and Social Affairs and other relevant departments) six from trade unions (4 from CATUS and 2 from UGS Nezavisnost), and six from employer representatives (all from the SAE). Although the SEC has a rather broad goal and mandate, in reality, its concentration is limited to setting the minimum wage and discussing numerous socioeconomic issues.

On the other hand, around 20 sectoral level collective agreements are in effect and thus publicly listed in accordance with The Rulebook on the Registration of Collective Agreements (*Official Gazette of the Republic of Serbia*, No. 22/97). Sectoral level collective agreements are the dominant form of collective agreements in the public sector, in which all but a few collective agreements were signed. The newest nationwide sectoral collective agreement in the private sector was signed in May 2023, covering the construction and building industry.

Change in legislation resulted in reducing the number of already signed sectoral collective agreements, which became ineffective after the enactment of the revised Labour Code in 2014. In addition, the revisions restricted the so-called ‘extended enforcement’ of sectoral collective agreements, which made most sectoral collective agreements in private, including financial services, unenforceable. The reasons are diverse, yet it is worth mentioning that SAE membership in many sectors does not cover enough private sector employees to secure automatic enforcement in these sectors. Furthermore, the revisions also undermined collective agreements at the company level since the regulator had prescribed that all collective agreements in force at the moment the new law was passed would become ineffective within a six-month period⁴⁸².

⁴⁸² Reljanović, M., Ružić, B., & Petrović, A. (2016). *Analiza efekata primene izmena i dopuna Zakona o radu*. Belgrade: Democracy Center Fund.

With both national and a wide range of sectoral level collective agreements non-existent, company-level social dialogue remains the most important, while company-level agreements are still the most common type of collective agreements in Serbia. Company-level negotiations are mostly done by large private sector firms as well as public companies that still exist. The union density in the public sector is higher than in the private sector. Also, while employees in the public sector are mostly covered by a collective agreement, collective bargaining in private companies is mainly reserved for the larger, often foreign-owned, or previously state-owned companies with a longer tradition of unionisation.

3. COLLECTIVE BARGAINING IN THE FINANCIAL SECTOR: COMMERCIAL BANKS VS. INSURANCE COMPANIES

Collective bargaining in the financial sector is conducted exclusively at the company level. There is no sectoral CBA in financial services. Moreover, no particular initiatives toward sectoral bargaining have been reported. Both sides, i.e. employers and trade unions, have not shown specific interest in sectoral collective bargaining. Moreover, some experts⁴⁸³ believe that “its importance may be viewed as inflated to a certain extent”. Similarly, other important actors (e.g. relevant Ministries and other institutions) have not expressed specific interest in supporting any activities toward initiating sectoral collective bargaining.

While there are several important associations representing the business interests in the sector, including Chamber of Commerce, Association of Serbian Banks, Association of Serbian Insurers and Serbian Association of Employers (SAE), only the last one is a recognised employers’ association and may thus in principle participate in sectoral collective bargaining. Serbian Association of Employers participated in sectoral collective bargaining regarding only one specific service sector (accommodation and food service activities)⁴⁸⁴, but not in regard to

⁴⁸³ For the purposes of their study, the authors interviewed a few experts (e.g. representatives of relevant trade unions and employers’ organisations as well as experts in the labour law and peaceful settlement of labour disputes).

⁴⁸⁴ Sectoral collective agreement on work engagement of pop artists and performers in the hospitality industry was signed between Serbian Association of Employers as a representative employers’ association and Independent union of pop artists and performers as the only representative trade union in this sector. In 2024, Serbian Association of Employers announced that extended enforcement applied in accordance with the official approval issued by the Government of Serbia. Source: Serbian Association of Employers, available at: <https://poslodavci.rs/poseban-kolektivni-ugovor-za-radno-angazovanje-estravno-muzickih-umetnika-i-izvodaca-ugostiteljstvu-dobio-prosireno-dejstvo-2/>

financial activities. On the side of sectoral trade unions relevant to financial services, the Republican Trade Union of Employees in Banks, Insurance Companies and other Financial Organizations of Serbia (BOFOS) has widespread activities⁴⁸⁵ and relatively big membership, yet it is not representative and thus not eligible to participate in sectoral collective bargaining. Another sectoral trade union, is SFOS (Trade Union of Financial Organisations of Serbia), gathering several company trade unions in commercial banks as well as insurance companies, yet also not granted representation in accordance with the Law.

Generally, the position of trade unions, both on the sectoral level (BOFOS, SFOS) as well as within companies (i.e. banks and insurance companies) is relatively weak. Trade union power continually deteriorated over the last decade, which also resulted in decreased collective bargaining coverage. Trade unions remained relatively strong only in the National Bank of Serbia (Serbian central bank) and the two commercial banks owned by the Republic of Serbia (Poštanska štedionica and Srpska banka) and at certain level in Dunav insurance company (with the Republic of Serbia as the majority shareholder) with long tradition in unionization from previous decades. This is in line with a statement provided by one of the experts we interviewed claiming that “trade unions are still strongest in the commercial banks and insurance companies with longer traditions of collective bargaining stemming from the period in which these were state owned”.

Typically, trade union members are mainly employees with longer work experience, while younger employees, as in other sectors, generally refrain from unionization. As a consequence, along with an increasingly competitive labour market, primarily regarding the supply side, individual work agreements overshadow collective bargaining in a number of financial institutions, including insurance companies and commercial banks. In such cases, the better negotiation power of young graduates and professionals stemming from a tightened labour market leads to growing inequality among company employees. Further, it additionally hinders potential for employees’ unionisation and collective

⁴⁸⁵ Including, for example: BOFOS (2024). *Equal opportunities in the labour market: Creating an inclusive labour market for all generations. Young and older workers - two sides of the same coin*. Kladovo: BOFOS; BOFOS (2023a). *Capacity building for workers’ organizations: Boosting negotiation skills: Win-Win Negotiations*. Serbia: BOFOS; BOFOS (2023b). *Healthy Workplaces: Prevention of work-related musculoskeletal disorders (MSDs) in the financial sector*. Serbia: BOFOS; BOFOS (2022). *Equal opportunities on the labour market. Gender Equality and the Fourth Industrial Revolution*. Serbia: BOFOS; BOFOS (2018a). *Industrial Revolution, and Social dialogue in financial sector: The future of labour relations in the financial sector*. Serbia: BOFOS. Full reports available on: <https://www.bofos.org.rs/info/edukacija.html>

bargaining. An expert also believes that, particularly younger workers, might stay “unaware of the necessity of protection of collective rights in addition to individual agreements”.

In an initiative for closing the generation gap in regard to unionisation and raising interest of younger workers for collective bargaining, BOFOS has organised a seminar fostering equal opportunities and an inclusive labour market for all generations. The new Declaration emphasising that the trade unions should promote intergenerational communication in the workplace and advocate the intergenerational transfer of knowledge was issued in 2024⁴⁸⁶ and widely promoted.

Due to inexistence of official data as well as the lack of public disclosure of private company collective agreements⁴⁸⁷, union density and collective bargaining coverage in insurance companies and commercial banks can only be estimated. Using personal interviews as well as accessible company annual reports, we assess union density and bargaining coverage rate lower than for the economy (around 25%). The figures are projected at around 10% in financial services, with higher density and bargaining coverage rate expected in commercial banks than insurance companies. The reason for such an assessment is at least twofold: 1) there are a few big banks still owned by the Republic of Serbia in comparison to one big insurance company and 2) number of employees in NACE 64 represents more than twice the number of employees in NACE 65. However, in regard to both commercial banks and insurance companies, it is also worth mentioning that international research shows that unionisation is typically lower among female workers⁴⁸⁸, who are found dominant in the financial sector in Serbia (60.5%, Figure 2). Below, we compare some of the most interesting cases in these two sub-sectors, referring to the existence/non-existence of collective bargaining.

While some commercial banks affiliated to strong foreign mother companies may still not have collective agreements (e.g. Raiffeisen bank AD), there are also a few examples showing that CBAs are considered an important part of their socially responsible activities (CSR). For example, ERSTE bank remains the best

⁴⁸⁶ BOFOS (2024), op. cit.

⁴⁸⁷ Available database of registered collective agreements in accordance with the Rulebook on registration of collective agreements, *Official Gazette of the Republic of Serbia*, No. 45/15 contains mostly sectoral CBAs in public administration and services, as well as a few company CBAs, typically public (i.e. owned by the Republic of Serbia).

⁴⁸⁸ Young, M. C. (2010). Gender Differences in Precarious Work Settings. *Relations Industrielles/Industrial Relations*, 65(1), pp. 74-97.

showcase of collective bargaining in financial services (NACE 64) in Serbia. According to their Annual Report on Corporate Social Responsibility, a successful collective bargaining process between the company and the representative trade union was completed in December 2023, “as a result of the readiness of both sides to continue working actively on promoting the rights of employees”. The new CBA was issued and equally applied among all employees (around 1,400 in total) with an easy access to its entire content through the Bank’s internal portal.⁴⁸⁹ Also, Uni Tel (Trade Union in Yettel bank, previously named Mobi Bank, which was owned by Telenor, Norwegian telecommunications company) announced signing the new collective agreement, for the period of 2023-2026.⁴⁹⁰

Another interesting case showing the current state of collective bargaining in financial services in Serbia is Banca Intesa, claiming in its Annual report for 2023 that “all employees are covered with CBA regardless of whether they are trade union members”⁴⁹¹. It has also been made evident that collective bargaining is promoted and supported by the mother company in San Paolo among its national branch offices, considering it an important part of their employee development and responsible business practice. Yet, the Annual Report data showed 3,079 employed workers in total, but only 332 (10.8%) of them being reported as trade union members. In accordance with the Labour Law⁴⁹² in Serbia to be regarded representative and thus eligible for collective bargaining a trade union must have at least 15% membership among company employees. In this case, it is not clear whether the total reported number of employees also includes those who are engaged by third parties (e.g. job agencies) and/or those who are engaged based on atypical work contracts that do not allow such workers to be trade union members and participate in collective bargaining.

⁴⁸⁹ ERSTE bank (2023). *ERSTE bank Corporate Social Responsibility Report 2023: The Bank is the People*. Novi Sad: ERSTE bank, pp. 34-35, available at: https://cdn0.erstegroup.com/content/dam/rs/ebs/www_erstebank_rs/Eng/Documentation/About-us/corporate-social-responsibility/Erste-Bank-ad-Nov-Sad-Corporate-Social-Responsibility-Report-2023-Bank-Is-the-People.pdf

⁴⁹⁰ Available at: <https://unitel.rs/kolektivni-ugovor-2023-2026/>

⁴⁹¹ Banka Intesa (2023). *Banka Intesa Annual Report for 2023*. Serbia: Banka Intesa, p. 65, available at: https://www.bancaintesa.rs/document/en/publications/BIB/Godi%C5%A1nji-izve%C5%A1taji/Godisnji_izvestaj_2023/Annual_Report_2023.pdf

⁴⁹² Labour Law, *Official Gazette of the Republic of Serbia*, No. 24/2005, 61/2005, 54/2009, 32/2013, 75/2014, 13/2017-Decision of the CC, 113/2017 and 95/2018 - authentic interpretation.

Finally, another case (OTP bank in Serbia)⁴⁹³ stands as yet another proof that presenting collective bargaining and employee coverage by CBAs has recently become an important part of banks sustainability and/or annual reports. In such reports, it is typically presented as part of companies' HR and CSR practices and along with the other issues concerning companies' code of ethics, working environment, employee wellbeing and satisfaction, career development and similar. The latter implies that in bigger financial services companies, collective bargaining has become an important part of a company's reputation, which may have an impact on its market position (both client and investors) as well as its employer branding on the labour market. While special care should be taken not to foster collective bargaining as yet another promotional tool rather than an important part of social dialogue, it may still be supported through issuing special certificates of good practices as well as competitions organized by various foundations and CSOs with an aim to motivate companies in performing socially responsible business practices.

Insurance companies also represent an interesting case for the analysis of the needs and potential for collective bargaining in financial services in Serbia. However, publicly available data on trade unions and collective agreements in insurance companies are even more limited than in the case of commercial banks. Internet search (both Google search and ChatGPT) of listed insurance companies provided limited data on active trade unions in insurance companies, including the company trade union in Dunav osiguranje (member of sectoral trade union SFOS, along with company trade unions in SAVA osiguranje and Triglav osiguranje as members of the same sectoral trade union), and company trade union DDOR (member of sectoral trade union BOFOS). On the other hand, Dunav osiguranje and DDOR are the only two named by ChatGPT as the exemplars in insurance sub-sector in which company collective agreements have been signed. Interestingly, based on our input to find collective agreements in insurance companies in Serbia, ChatGPT advised researchers as follows: "for specific information on the existence and content of collective agreements in a certain insurance company, it is recommended to contact that company or its trade union directly." However, consistent with previously described collective bargaining in commercial banks, we focused on publicly available documents, including insurance companies' Annual reports, Codes of Ethics, or other relevant documents published on their websites or relevant internet sources.

⁴⁹³ OTP Bank (2023). *OTP Bank Sustainability report for 2023*. Serbia: OTP Bank, pp. 31-32, available at: <https://www.otpbanka.rs/wp-content/uploads/2024/05/eng-otp-izvestaj-o-odrzivom-poslovanju-1652024.pdf>

Based on collected data, there are only a few relatively recognisable cases of collective bargaining in insurance companies, including Dunav osiguranje, DDOR Novi Sad and Triglav osiguranje. However, the collective bargaining agreement has been explicitly mentioned only in the case of Dunav insurance company, in its 2022 Annual Report⁴⁹⁴ as well as in the Annual Audit in 2023 conducted by the State Audit Institution in Serbia⁴⁹⁵.

On the one hand, DDOR insurance company being fully state-owned before 2012⁴⁹⁶ like other previously mentioned cases has longer tradition in unionisation and collective bargaining. Various documents and information (e.g. Careers, Top Employer Certificate, Annual Reports on Gender Equality) available on the company website⁴⁹⁷ show its strong HR commitment to employee development through education and training, provision of equal and gender-neutral opportunities for its workers, fostering open dialogue and assuring various benefits. Still, unlike in the years before 2012, the existence of a company's collective bargaining agreement has not been explicitly mentioned.

Finally, the third selected case is Triglav osiguranje, another insurance company present on insurance market in Serbia for more than five decades⁴⁹⁸. Long company history dating back to seventies of the last century has also granted its long tradition in unionisation and collective bargaining. The company started operations in Serbia in 1972 (by Sava insurance agency with headquarters in Ljubljana, Slovenia) and was renamed Triglav in 1976. After considerable changes over 1990s, the company was sold to Triglav group from Slovenia, who now holds 100% of its capital. In regard to the collective bargaining agreement, Triglav osiguranje is similar to the previously described DDOR insurance company. The existence of such a document has not been explicitly named, yet the company is listed as a member of SFOS. Also, the company's Code of Ethics emphasises responsible practices, including taking proper care of their employees. In line with it, it claims that "special care is devoted to the development of key and promising co-workers and to leadership development" as well as that

⁴⁹⁴ Available at: <https://www.dunav.com/o-nama/izvestaji/nefinansijski-izvestaji/>

⁴⁹⁵ Available at: <https://www.dri.rs/storage/newaudits/2023-4-Kompanija%20Dunav%20osiguranje.pdf>

⁴⁹⁶ The company became part of Unipol Assicurazioni S.p.A in 2012, currently controlling 100% of its capital.

⁴⁹⁷ <https://www.ddor.rs>

⁴⁹⁸ <https://www.triglav.rs/>

strengthening awareness of the importance of safety and health at work is granted through training of employees and continuous internal communication.⁴⁹⁹

4. SMART COLLECTIVE BARGAINING IN THE AFTERMATH OF DIGITAL TRANSFORMATION AND INNOVATIVE WORK ARRANGEMENTS

Digital transformation, along with innovative work arrangements, brings new challenges to labour relations on both sectoral and company levels, thus calling for an improved approach in collective bargaining, referred to as “smart collective bargaining“. Digital transformation has changed the essence of many jobs, which has resulted in raising fears of job losses and employment uncertainty, particularly among lower-skilled and older generations of workers. It has also opened new space for further introducing innovative work arrangements (e.g. remote work, hybrid work, flexible working time, annualised hours)⁵⁰⁰, some of which may further compromise protection of collective rights on company level.

Smart collective bargaining should thus primarily be focused on improved collective agreement contents over time. To achieve it, bargaining process needs to be continual and repeated in short time periods (e.g. on semi-annual or annual basis). For example, Erste Bank recently adopted the new CBA which introduced changes with regard to defining higher amounts of the minimum wage by pay grade, agreed increase in the number of days of annual leave based on socio-economic criteria for persons with disabilities from one to three working days.⁵⁰¹ Additionally, smart bargaining assumes on-going consultations between the parties to allow prompt reactions when needed. It is in line with the undergoing changes, resulting from technological development, digital transformation in particular, but also new challenges stemming from social and ethical standards and behaviours, as well as wider developmental goals on global level

Smart bargaining is inclusive, flexible, based on principles and mutual interests that are openly discussed and used for problem solving. As promoted in BOFOS

⁴⁹⁹ Triglav Group (2023). *Code of the Triglav Group*. Ljubljana: Triglav, available at: https://www.triglav.eu/wps/wcm/connect/a898cf34-969a-4eb8-8a40-1623215b41dd/Kodeks_Triglav_A4_2023_ANG.pdf?MOD=AJPERES&CONVERT_TO=url&CA_CHEID=ROOTWORKSPACE-a898cf34-969a-4eb8-8a40-1623215b41dd-pdyrhy.

⁵⁰⁰ Innovative work arrangements taken into consideration in this chapter, exclude other types of flexible work contracts (e.g. temporary, freelance, seasonal working), as such work arrangements do not grant employment status which is a precondition for participation in collective bargaining.

⁵⁰¹ ERSTE bank (2023), op. cit., pp. 34-35.

Collective Bargaining guide, “negotiation is a part of life, an extremely important skill to be learned and applied. Since changes are constant and universal, from legislation to the people we work with, it is impossible to solve new problems always in the same way.”⁵⁰²

Education and training play an important part in smart bargaining. To increase bargaining coverage, introducing new actors is of utmost importance. In particular, newly employed younger workers need to be included in collective bargaining. To achieve it, fostering communication among generations as well as transfer of knowledge and experience are crucial. Yet, development of trust remains among the basic prerequisites for mutual understanding and increasing the scope of collective bargaining.

Smart collective bargaining should lead to CBAs guaranteeing higher level of protection of employees' rights compared with the rights granted by the Labour Law. Collective agreement is signed in the interest of employers, but employers also find their interest in collective bargaining since it assures a supportive work environment and satisfied employees as well as partnership with trade unions in coping with various business and other challenges.

As part of smart collective bargaining, BOFOS also promotes win-win negotiation strategies, assertive communication and developing skills that would help members of negotiation teams to develop and communicate their negotiation power on an equal basis with the employers.⁵⁰³ Other stakeholders also see smart bargaining as strongest asset of trade union representatives, which should be based on proper knowledge and skills as well as the use of strong and objective arguments. Negotiators must be experienced, competent, trustworthy and reliable people. Smart negotiations require good preparation and setting realistic goals. Smart negotiators are flexible, ready to adapt to the other party's negotiation style and to analyse and discuss problems to find as many alternative solutions as possible.

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⁵⁰² BOFOS (2018b). *Bofosov priručnik za kolektivno pregovaranje*. Serbia: BOFOS, available at: https://www.bofos.org.rs/organizacija/kolektivno_pregovaranje.html

⁵⁰³ BOFOS (2023a), op. cit.

PART IV

**DIGITAL TRANSFORMATION
AND TECHNOLOGICAL
INNOVATION IN INSURANCE**

Chapter 18.

KEY INFORMATION TECHNOLOGIES IMPACTING THE ADVANCEMENT OF THE INSURANCE INDUSTRY

As of recently, the insurance industry has been at a pivotal point marked by significant innovation and transformation. The advancements in automation, AI, distribution channels, and cloud computing have established a robust foundation for a more dynamic future focused on customer needs.

Looking ahead, these trends are expected to intensify, with efforts directed toward scaling solutions, improving processes, and tackling challenges such as regulatory compliance and skill shortages. Insurers are increasingly utilising generative AI to revolutionise areas like claims processing and customer support. Additionally, embedded insurance models, where coverage is integrated directly into the customer journey, are becoming more prevalent, redefining the value insurers provide.

Process automation is transforming the insurance industry by moving beyond just reducing costs to becoming a key driver of operational excellence. Insurers are increasingly investing in advanced IT solutions to streamline core back-office functions like claims processing, underwriting, and policy management. This shift aims to eliminate inefficiencies by replacing outdated legacy systems with innovative technologies such as Robotic Process Automation (RPA), Artificial Intelligence (AI), and Machine Learning (ML).

Automating these processes helps insurers minimize delays, improve accuracy, and respond more quickly to customer needs and market shifts. The advantages extend past cost savings, leading to greater operational efficiency, faster service delivery, and higher customer satisfaction. It also enhances agent performance and employee retention. Overall, this comprehensive automation approach enables insurance companies to operate more smoothly, stay agile, and remain competitive in a fast-changing industry. By harnessing the power of process automation, insurers free up the fuel for innovation, sparking a transformation that reshapes their business model to thrive in today's fast-moving, ever-changing market landscape. Cloud computing continues to be a vital enabler, offering the necessary agility, scalability, and compliance support for the industry's ongoing digital transformation. Overall, these trends will significantly influence how insurers operate, innovate, and connect with their customers.

1. INSURANCE COMPANIES' MIGRATION TO CLOUD SOLUTIONS

Insurance companies are going through an intensive process of digital transformation, with cloud technology as an important factor in modern business. Insurance companies have traditionally been wary of adopting cloud technologies and have been slower in moving to cloud solutions compared to other financial sectors. The reason behind the slower transition to cloud solutions is the complex legislative framework that requires additional adjustments and compliance with regulations such as GDPR⁵⁰⁴ and Solvency II⁵⁰⁵. However, cloud technologies are becoming more advanced and more secure, which is why insurance companies are increasingly investing in migration to cloud platforms.

Digitisation and advanced technologies such as artificial intelligence further highlight the need to move to cloud infrastructure. According to the Global Insurance Market Report 2024⁵⁰⁶, digitisation and AI are significantly improving insurance processes, reducing costs and improving customer experience. However, challenges such as high liquidity risks and cybersecurity risks require careful management. This is exactly where the cloud plays a key role. It gives insurance companies a scalable infrastructure for data analysis, effective risk management and optimisation of business operations.

All these factors increase the adoption of cloud solutions, especially in the segments of data processing, service personalisation and risk management. Companies that recognise these advantages and move to cloud infrastructure gain a greater competitive advantage.

Current situation and accelerated migration to cloud solutions

The regulatory framework governing the use of cloud technologies in the insurance sector is becoming increasingly clear. It allows companies a faster and more secure migration from traditional IT infrastructures. Previous strict regulations and uncertainties around compliance were the key factors that slowed down insurance companies' transition to cloud solutions. However, the new IFRS

⁵⁰⁴ General Data Protection Regulation regulates the way of collecting, processing and storing EU citizens' personal data.

⁵⁰⁵ The EU regulatory framework related to insurance and reinsurance companies.

⁵⁰⁶ International Association of Insurance Supervisors (2024). *Global Insurance Market Report (GIMAR) 2024*, Basel: IAIS, p. 3.

9 and IFRS 17⁵⁰⁷ standards put pressure on insurance companies to improve data management and financial reporting transparency, making the cloud a more attractive choice⁵⁰⁸. Also, more and more regulators recognise cloud technologies as a safe and effective solution, provided that data protection, information independence and risk management requirements are met.

Software-as-a-Service (SaaS) is becoming an increasingly dominant model in the insurance sector, as it allows faster implementation, reduces initial costs and easier integration with artificial intelligence (AI) and analytics tools. According to a January 2025 Carrier Management⁵⁰⁹ report, insurance companies are increasingly embracing cloud computing and SaaS technologies due to their agility, scalability and cost effectiveness. By 91% of the world's insurance companies have started migrating to cloud technologies, which is a sharp rise compared to only 37% in 2020⁵¹⁰. According to Abbas et al. (2015)⁵¹¹, cloud computing enables more efficient management of large amounts of data through advanced recommendation systems, which helps insurance companies optimise offers and reduce operating costs. This trend is especially true for personalised insurance plans that rely on data analysis and automated decision-making processes.

Key factors driving the shift to cloud infrastructure

Insurance companies are increasingly moving to cloud infrastructure because it improves operational efficiency, flexibility and data security. Cloud solutions reduce IT infrastructure costs, improve process automation and allow for more efficient management of large amounts of data. In addition, they enable faster analysis and data-driven decision-making, which is key to insurance product optimization and risk management. According to Mateen et al. (2023)⁵¹², cloud technology brings insurance companies greater scalability and makes them more

⁵⁰⁷ International Financial Reporting Standards are issued by the International Accounting Standards Board (IASB) and refer to financial instruments and insurance contracts.

⁵⁰⁸ International Association of Insurance Supervisors (2024), op. cit., p. 5.

⁵⁰⁹ <https://www.carriermanagement.com/news/2025/01/07/270162.htm>

⁵¹⁰ <https://www.capgemini.com/news/press-releases/91-of-banks-and-insurers-have-initiated-their-cloud-journey-yet-many-are-unable-to-realize-full-business-value/>

⁵¹¹ Abbas, A., Bilal, K., Zhang, L., & Khan, S. U. (2015). A cloud based health insurance plan recommendation system: A user centered approach. *Future Generation Computer Systems*, 43, p. 100.

⁵¹² Mateen, A., Khalid, A., Lee, S., & Nam, S. Y. (2023). Challenges, issues, and recommendations for blockchain and cloud-based automotive insurance systems. *Applied Sciences*, 13(6), 3561, pp. 19-20.

resilient to challenges such as data security and fraud prevention, enabling more efficient real-time data storage and analysis.

Cloud technology plays a key role in the implementation of artificial intelligence and advanced analytics, allowing for more accurate risk assessment and faster claim handling. According to Sandhu (2021)⁵¹³, big data and cloud computing are closely related because technological changes allow for distributed processing, parallel technologies, large storage power and real-time analysis of heterogeneous databases. This allows insurance companies to analyse vast amounts of data faster and more efficiently, which improves insurance product personalisation, fraud detection and valid decision-making. Also, the use of big data technologies improves fraud detection, identification of the insured behaviour patterns and optimisation of policy prices.⁵¹⁴

In addition to analytics, cloud technology brings significant benefits in security and regulatory compliance. Modern cloud providers offer end-to-end encryption, multi-factor authentication and zero-trust architecture, which reduces the risk of cyber attacks and data loss. Mateen et al. (2023) emphasise that cloud infrastructure enables insurance companies to better control data access and have greater resistance to cyber threats, thereby increasing transparency and user trust.⁵¹⁵

Due to these advantages, more and more insurance companies are rapidly moving to the cloud, not only to reduce operating costs, but also for a better ability to adapt to market changes. Investing in cloud technologies is no longer an option, but a strategic necessity for insurers who want to remain competitive and respond to the growing demands of the digital economy.

The impact of cloud technologies on competitiveness and risks in the insurance sector

Insurance companies that timely adopt cloud technologies become more competitive because they can innovate faster, optimise business processes and improve user experience. By using cloud platforms, insurers significantly reduce IT infrastructure costs and speed up decision-making thanks to advanced analytics and process automation. According to the Global Insurance Market

⁵¹³ Sandhu, A. K. (2021). Big data with cloud computing: Discussions and challenges. *Big Data Mining and Analytics*, 5(1), p. 36.

⁵¹⁴ Handoko, B. L., Mulyawan, A. N., Tanuwijaya, J., & Tanciady, F. (2020). Big data in auditing for the future of data driven fraud detection. *International Journal of Innovative Technology and Exploring Engineering*, 9(3), p. 2904.

⁵¹⁵ Mateen et al. (2023), op. cit., p. 19.

Report 2024⁵¹⁶, digitisation and AI technologies reduce costs and improve customer experience. At the same time, regulators increasingly focus on the risks associated with the application of artificial intelligence and cloud infrastructure.

On the other hand, companies that delay the transition to the cloud face increasing operational risks, regulatory challenges and loss of market share. Outdated IT systems make it difficult to comply with new regulations and prevent rapid adaptation to market changes. Global Insurance Market Report (GIMAR) reports⁵¹⁷ show that insurance companies that do not optimise processes using cloud technologies are losing their competitive advantage, as their traditional systems face slower data processing and increased operational costs. The growing use of cloud solutions brings greater operational efficiency as it reduces costs and automates business processes. Research shows that switching from outdated local IT systems to the cloud can reduce IT infrastructure and maintenance costs by around 30%.⁵¹⁸ Such savings derive from economies of scale and cost per use, eliminating the need for large capital investments in hardware. In addition, cloud technologies enable insurers to optimise workflows, reduce manual errors and speed up data processing.

In the long term, cloud technologies will play a key role in the development of the insurance industry, allowing insurance companies to connect with advanced technologies such as blockchain, IoT and artificial intelligence. As digitisation advances, insurance companies will need to adapt or risk losing their competitive advantage over those that have already fully implemented cloud strategies.

2. GROWING IMPORTANCE OF LOW-CODE/NO-CODE PLATFORMS IN INSURANCE

In the modern insurance sector, technological innovation is becoming a key factor in competitiveness and sustainable growth. Increasing demands for agility, operational efficiency and faster delivery of digital solutions are driving insurers to adopt low-code/no-code platforms. These technologies enable accelerated implementation of software solutions, business process optimization and flexibility in adapting to dynamic market conditions. In addition, their application significantly reduces IT development costs and increases the involvement of business users in the creation of digital products and services.

⁵¹⁶ International Association of Insurance Supervisors (2024), op. cit., p. 23.

⁵¹⁷ Ibid, p. 17.

⁵¹⁸ <https://inubesolutions.com/resource/exploring-the-transformative-benefits-of-insurance-cloud/>

Low-code/no-code platforms vs. traditional software solutions

Low-code and no-code platforms are becoming key tools for insurance companies to accelerate product development, automate processes and empower non-technical staff. The primary advantage of these tools is the speed of implementation. Traditional development of insurance software solutions can take months or even years, especially due to complex business rules and regulatory requirements. Low-code platforms simplify this process by providing visual interfaces and predefined templates, which significantly shorten development time.⁵¹⁹ Insurers are seeing significant improvements in speed of functionality, with most insurance companies adopting low-code technology reporting at least a 30% increase in development speed.⁵²⁰

Faster application delivery allows insurers to more easily adapt to customer needs, which is critical in an era where fintech and insurtech startups are innovating at high speed. The greater scalability afforded by the low-code methodology means that insurers can test new products or processes within weeks and then adjust them based on feedback. This agility in product development directly contributes to growth, as it allows insurers to market innovative products (e.g. on-demand insurance or usage-based products) before competitors.

Another key advantage of low-code/no-code technologies is process automation. Many insurance processes involve repetitive tasks that are amenable to automation. Low-code development enables the rapid creation of applications or workflows that automate routine tasks, often through integration with existing core systems. For example, low-code solutions have been used to optimise claims processing by enabling automatic data entry, validation and communication, thereby reducing errors and speeding up the claim settlement process.⁵²¹ Similarly, low-code tools can implement automated risk assessments, allowing insurers to make faster and more accurate decisions. By using low-code platforms, insurance companies can increase operational efficiency, reduce costs and improve user experience.

Many insurance companies have already realised significant benefits from the implementation of low-code/no-code technologies. For example, Allianz, one of the world's largest insurance companies, used low-code platforms to digitise

⁵¹⁹ <https://insurance-edge.net/2024/08/02/low-code-platforms-revolutionizing-the-insurance-sector/>

⁵²⁰ <https://www.mendix.com/blog/low-code-the-insurance-modernization-toolkit/>

⁵²¹ <https://insurance-edge.net/2024/08/02/low-code-platforms-revolutionizing-the-insurance-sector/>

internal workflows and accelerate the development of customer service applications.⁵²² Allianz has developed a modular “Building Block Platform” for the flexible creation of “plug and play” digital ecosystems. Another example is Zurich Insurance Group, which has adopted low-code tools to improve operational efficiency and create innovation for clients. Their team used low-code platforms to build applications, including an advanced claims processing tool and the “FaceQuote” app, which allows customers to get an insurance premium estimate using a photo.⁵²³ These applications have helped Zurich improve user experience and optimise operations, while at the same time reducing IT development costs.

Low-code/no-code technologies are becoming an integral part of insurers’ digital strategy. Industry analysts predict strong growth in this area – for example, the global market for low-code applications is estimated to be around \$26.9 billion in 2023, an increase of 20% compared to 2022.⁵²⁴ These projections confirm that low-code technologies are gaining importance.

Challenges and risks of applying low-code/no-code platforms in insurance

Although low-code/no-code platforms bring significant advantages, their application in the insurance sector also carries certain risks that companies must carefully manage. Safety and regulation are one of the key challenges. By enabling application development outside of the IT sector, low-code/no-code tools can lead to oversight problems, creating so-called shadow IT, i.e. systems developed without formal IT control.⁵²⁵ These systems often do not undergo rigorous security checks, increasing the risk of data leaks and non-compliance with regulatory standards. In the insurance industry, where data protection and regulatory compliance are crucial, any security breach can lead to major problems and loss of customer trust.

In order to reduce these risks, insurance companies must establish low-code/no-code development management frameworks. Most leading insurance companies already implement an approach in which the IT department retains control over

⁵²² <https://binariks.com/blog/low-code-no-code-for-insurance/>

⁵²³ Ibid.

⁵²⁴ <https://www.infosysbpm.com/blogs/insurance/no-code-and-low-code-platform-in-insurance-the-future-is-multi-platform.html>

⁵²⁵ <https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/tech-forward/low-code-no-code-a-way-to-transform-shadow-it-into-a-next-gen-technology-asset>

business users who develop applications, forming teams to manage innovation and ensure security standards.⁵²⁶

In addition to security challenges, the technical limitations of low-code/no-code platforms can make their application in complex insurance processes difficult. Many tools are designed as general software platforms and lack specialized support for functions such as risk assessment, policy management or claims processing.⁵²⁷ Insurers often have to make additional adjustments to these systems, which can cancel out the time and cost savings. Also, integration with outdated IT systems is a significant problem. Large insurers often use outdated IT systems that are not adapted to modern API connections, making it difficult to connect low-code applications with existing databases and computer systems.

Another challenge is the limited adaptability of low-code/no-code solutions. Although they enable rapid application creation, the flexibility of these platforms can be limited compared to traditional software development. Some specialized insurance applications may require advanced algorithms or specific requirements that low-code tools do not support. In addition, insurers that rely on one software vendor may face a vendor lock-in situation, where it is difficult to switch to another solution due to technical or contractual limitations.⁵²⁸

Finally, organisational changes and employee training are key factors in successful implementation. Although low-code/no-code tools are intuitive, they still require user training in order to effectively create applications in line with business needs and security requirements. Insurers must invest in training programs and clearly define what types of applications non-technical users can develop. To sum up, although low-code/no-code tools bring greater agility, insurers must carefully manage security, technical and organisational challenges to fully exploit their benefits.

⁵²⁶ <https://fivem.llc/modernizing-insurance-no-code-low-code/>

⁵²⁷ <https://binariks.com/blog/low-code-no-code-for-insurance/>

⁵²⁸ Pendyala, V., & Srirangam, R. K. (2024). Democratizing data insights: the impact of no-code/low-code platforms on business intelligence visualization. *International Journal of Research in Computer Applications and Information Technology (IJRCBIT)*, 7(2), pp. 647-661.

3. APPLICATION OF ARTIFICIAL INTELLIGENCE IN INSURANCE

The "Renaissance period" of artificial intelligence

In the last few years, we have witnessed a very rapid development of artificial intelligence (AI), which has been labelled as the "Renaissance period" of artificial intelligence. Compared to other technologies, artificial intelligence is much more powerful. The main reason for this is that AI is not a single technology, platform or tool, but a meta-technology that has enormous transformational power over other technologies. Artificial intelligence is the creator of tools and platforms, so it has the power to generate many systems.⁵²⁹

The history of artificial intelligence is about seven decades old. Its course of development was not linear, but rather a series of ups and downs. The following factors contributed to the latest "Renaissance" of the development of the field of artificial intelligence (the famous trinity of artificial intelligence⁵³⁰):

- vast amount of data – big data,
- Graphics Processing Units (GPU) hardware, and
- AI (ML) algorithms.

One of the basic characteristics of artificial intelligence is that the techniques and tools of artificial intelligence have the ability to be upgraded, i.e. to learn from data, which other types of software do not have. Artificial intelligence technologies move in the direction of implicit programming, where computers learn by themselves, as opposed to explicit programming, where a person "tells" the computer what to do.

AI evolution has gone in the following direction:

- The appearance of the *first theories in the field of artificial intelligence* was recorded during the 1950s;
- *Machine learning algorithms* were developed during the first decade of the 21st century;
- The development of *deep learning algorithms* (Recurrent Neural Networks, Convolutional Deep Neural Networks, Deep Feed Forward, etc.) dominated during the 2010s;

⁵²⁹ Suleyman, M., & Bhaskar, M. (2024). *The Coming Wave: Technology, Power and Twenty-first Century's Greatest Dilemma*. Entropia.

⁵³⁰ Kureishy, A., Meley, C., & Mackenzie, B. (2019). *Achieving Real Business Outcomes from Artificial Intelligence, Enterprise Considerations for AI Initiatives*. Newton, MA: O'Reilly Media, Inc.

- The development of *generative AI* is characteristic of the first half of the 2020s, i.e. the current period.

The application of Generative AI in Insurance

Generative AI (GenAI) is a field of artificial intelligence "that can create original content – such as text, images, video, audio or software code – in response to a user's prompt or request".⁵³¹ Generative AI belongs to the field of Machine Learning, or more precisely to the field of Deep Learning algorithms.⁵³²

In the field of GenAI the rapid development of Large Language Models (LLMs) has been noted. Among these models, the most famous is the ChatGPT model, which provides real-time answers to the user's questions in a human-like manner. This program can not only answer questions, but it can also write poems, stories, essays, solve math problems, classify things, write programming codes, etc. The application of ChatGPT is promising in many industries, including the insurance industry. In general, the application of GenAI in insurance can be manifold. It can contribute to increasing efficiency, effectiveness, operational efficiency, as well as improving customer service.⁵³³

Here are the main areas in insurance where GenAI can have a significant impact:⁵³⁴

- **Risk assessment and management:** GenAI can improve the management process, providing a more informed decision-making process regarding the approval of the insurance policy and the amount of the insurance premium, as well as creating simulations on various possibilities regarding the coverage for the particular claims;
- **Underwriting process:** GenAI is expected to offer faster and more efficient preparation of personalised insurance policies and ensure greater customer satisfaction;

⁵³¹ Stryker, C., & Scapicchio, M. (2024). What is generative AI? *IBM*, March 22, 2024, <https://www.ibm.com/think/topics/generative-ai>

⁵³² <https://communities.sas.com/t5/SAS-Communities-Library/Where-does-GenAI-fit-within-the-AI-landscape/ta-p/915000>

⁵³³ Pavlović, B. (2023). Application of ChatGPT in Insurance. In: *Challenges and Insurance Market's Response to the Economic Crisis*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, Chapter 25, pp. 455-473.

⁵³⁴ Introduction to the Role of Generative AI in Insurance, <https://aisera.com/blog/chatgpt-generative-ai-in-insurance/>

- **Insurance claims processing:** GenAI can contribute to the significant improvement of insurance claims processing, such as the automation of certain processing tasks (input, processing and analysis of data, preparation of reports, etc.). GenAI can perform a detailed analysis of data of various types, identify trends, as well as significant deviations and outliers, thus providing an opportunity to predict future trends and prevent fraud. Also, GenAI can sort requests according to urgency and complexity, group them, and summarise voluminous text into shorter reports. All of the above contribute to lowering costs and shortening the processing time of requests. A good combination of the work of GenAI and human experts can generally achieve better performance of the entire insurance process, as well as improve user satisfaction;
- **Offering personalised products and services to clients:** GenAI provides the opportunity for insurance companies to offer their users specific products and services that are aligned with their characteristics, profiles, claims history, as well as, with their preferences. For these purposes, companies can prepare special AI platforms equipped with GenAI tools for conversation and providing answers to clients on various inquiries regarding the conditions and insurance policy. As part of this initiative, GenAI can include options such as an insurance copilot, which would contribute to the automation of issuing documents and insurance policies;
- **Extraction of useful business insights:** As in many other industries, GenAI can be applied in the insurance industry as well to analyse a vast amount of data, mainly unstructured data, making summary reports and recommendations for further steps that need to be taken in the company.

The latest trends in the field of Generative AI

Bearing in mind that GenAI has become an extremely important topic in many industries, we show here further development perspectives of this type of artificial intelligence. We will recall the application of a well-known graphic display – Gartner's hype cycle, which can describe the life cycle of any new technology.⁵³⁵ According to this presentation, the following five stages of the technology maturity can be distinguished:

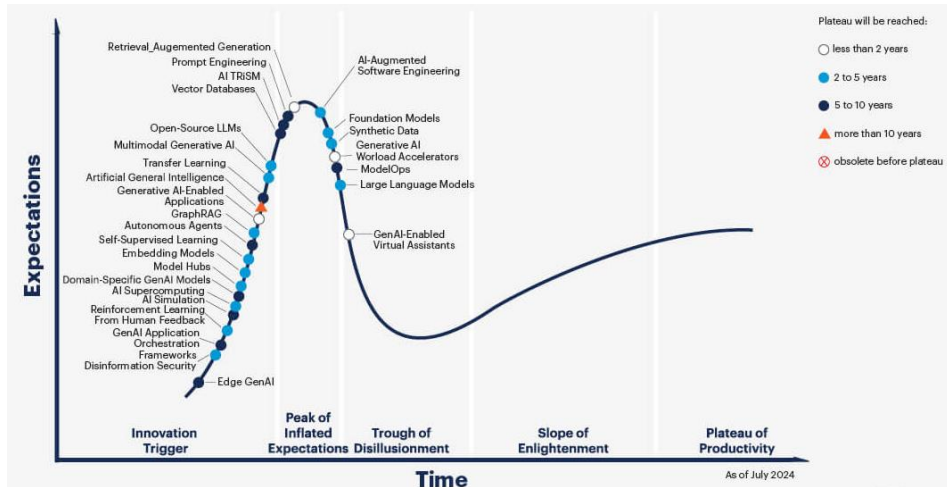
- Technology Trigger,
- Peak of Inflated Expectations,
- Trough of Disillusionment,

⁵³⁵ Linden, A., & Fenn, J. (2003). Understanding Gartner's hype cycles. *Gartner*, <https://web.archive.org/web/20230627173309/https://www.gartner.com/en/document/s/396330> (accessed 27.6.2023)

- Slope of Enlightenment, and
- Plateau of Productivity.

The GenAI has already passed the second stage of the life cycle and has entered the third stage – the Trough of Disillusionment (details can be seen on the Hype Cycle for Artificial Intelligence graph⁵³⁶). The development process of GenAI can be seen in Figure 1.

Figure 1. Hype Cycle for Generative AI



Source: Chandrasekaran, A. (2024). What's Driving the Hype Cycle for Generative AI. Gartner, November 14, 2024, <https://www.gartner.com/en/articles/hype-cycle-for-genai>

According to Gartner's review, various generative artificial intelligence technologies can be grouped into four categories: GenAI models, AI engineering tools, applications and use cases, and enablement techniques and infrastructure. The first group of GenAI models consists of the following technologies:

- **Foundation models** – Machine learning models with a large number of parameters that represent high-dimensional data, trained on a vast amount of data and can be applied in many different practical examples. Large Language Models (LLMs) are one example of these models;

⁵³⁶ Jaffri, A. (2024). Explore Beyond GenAI on the 2024 Hype Cycle for Artificial Intelligence. Gartner, November 11, 2024, <https://www.gartner.com/en/articles/hype-cycle-for-artificial-intelligence>

- **Embedding models** – Algorithms used in machine learning for data encapsulation in order to facilitate work in a multi-dimensional space and translate complex data into vector embeddings;
- **Domain-specific GenAI models** – Models that are prepared to respond to the needs of specific industries. For example, domain-specific LLMs are special LL models that are prepared (trained) for a certain area or a special industry;
- **Edge GenAI** – GenAI algorithms and models that are used directly on local edge devices, such as sensors, IoT devices, cameras, microcontrollers, smartphones, PCs, laptops, or edge servers;
- **Artificial general intelligence (AGI)** – One area or type of artificial intelligence, which implies that a machine can perform any cognitive task that a human can perform.⁵³⁷

Another group of AI technologies consists of AI engineering tools. The main innovations in this area are: AI TRiSM – AI trust, risk and security management, Disinformation security, GenAI application orchestration frameworks and GraphRAG – techniques for improving retrieval-augmented generation (RAG) systems. From the field of AI applications and use cases, GenAI-enabled virtual assistants, autonomous agents, and the use of synthetic data obtained through simulation for training ML models stand out. In the fourth area, the emphasis is on innovations related to techniques and infrastructure, such as self-supervised learning, transfer learning, AI supercomputing, AI workload accelerators, AI simulation. Figure 1 reveals that all the mentioned technologies are in the first and second stages of maturity and implementation.

The future of Generative AI is marked by a high growth rate. According to one estimate, the growth of GenAI is expected at a compound annual growth rate of 37.3% from 2023 to 2030.⁵³⁸ Also, it is estimated that only 5% of companies implemented GenAI applications in 2023, and predictions are that more than 80% of companies will use GenAI APIs or models in their production environment by 2026.⁵³⁹

⁵³⁷ <https://aws.amazon.com/what-is/artificial-general-intelligence/>

⁵³⁸ Arya, N. (2023). The Future of AI: Exploring the Next Generation of Generative Models, *KD nuggets*, May 22, 2023, <https://www.kdnuggets.com/2023/05/future-ai-exploring-next-generation-generative-models.html>

⁵³⁹ Chandrasekaran (2024), op. cit.

4. EMBEDDED INSURANCE – IT SUPPORT

The concept of embedded insurance refers to the integration of insurance products and services into products and services from other fields and industries. The idea of embedded insurance is not new. The recent interest for this idea has been fueled by various technological innovations. Unlike classic insurance, where the insurance process is separated from the products or services it covers, this type of insurance is included in the process of buying products and services and happens practically at the point of sale.

A classic examples of this type of insurance are: car insurance when buying and/or renting a car, travel insurance when booking a flight, electronic insurance – insurance plans for electronics and appliances, home appliances and furnishings, event ticket insurance — that covers cancellations or inability to attend the event, and so on.

Embedded insurance provides a specific experience for clients, such as:

- **Convenience:** The client can shorten the time and effort of involvement in purchasing insurance;
- **Customisation:** Instead of a uniform service for all clients, the client can be offered personalised services;
- **Accessibility:** Insurance is brought closer to the client, so even those clients who have not thought about buying insurance can relatively easily decide on it;
- **Improved coverage:** With embedded insurance clients can reach specific coverages that cannot be offered by traditional insurance;
- **Lower costs:** It is to be expected that policies are cheaper when purchased together with a product or service compared to the situation when an insurance policy is purchased separately.

In addition to the previous characteristics, embedded insurance provides a number of advantages for companies, such as: new revenue streams, increase customer retention, customer loyalty and engagement, cross-selling opportunities, open opportunities for creating new or changing existing business models, as well as opportunities to attract new investors, brand and market differentiation, etc.

In terms of technologies that support the concept of embedded insurance, the first is the application of cloud computing. The cloud-based platform *Insurance-as-a-Service* (IaaS), offering various insurance services as a software product, stands out. Other information technologies that support the idea of embedded insurance include *Application Programming Interfaces* (APIs) technology for connecting

service providers and users, while artificial intelligence and machine learning (ML) technology is used to perform data analysis that is essential for the implementation of the risk assessment process, as well as for the provision of specific personalised services and options for the customer. This type of analysis can be carried out on-premises, but there is an advantage to using cloud technology when the company stores a large amount of data in the cloud.⁵⁴⁰ The processing and analysis of large amounts of data represents a significant challenge for every company, as it requires changing or redesigning the concept of business analytics according to new needs.^{541, 542}

Obviously, the aforementioned innovations in the field of information technology create opportunities for insurance companies to relatively easily integrate personalised insurance offers using APIs and open access to their products. It is important to note that in the domain of embedded insurance, an important role is played by Insurtech companies (insurance technology companies), companies that create and develop different technological variants for the digitisation of insurance processes and services.

The concept of embedded insurance, together with the technology that supports it, can be seen as a game-changer for the insurance industry, as it provides the opportunity for insurance companies to realize in practice the well-known business slogan "provide the right services to the right person in the right place".

Table 1 shows the different models of embedded insurance and the corresponding IT support.

⁵⁴⁰ Chroneos Krasavac, B., Soldić-Aleksić, J., & Petković, G. (2016). The Big Data Phenomenon – Business and Public Impact. *Industrija*, 44(2), pp. 117-144.

⁵⁴¹ Soldić-Aleksić, J., Chroneos Krasavac, B., & Karamata, E. (2020). Business analytics: new concepts and trends. *Management: Journal of Sustainable Business and Management Solutions in Emerging Economies*, 25(2), pp. 15-29.

⁵⁴² Chroneos Krasavac, B., & Kalićanin, Đ. (2020). The Impact of Big Data and Business Analytics on the Competitiveness of Insurance Companies. In: *Insurance market after COVID-19*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 383-401.

Table 1. Technical requirements for different types of embedded insurance models

Embedded insurance model	Supporting information technologies
Integration with products/services	API integration: Seamless integration of insurance functionalities into third-party platforms. Digital platforms and core systems: Support for integration and automation. User experience design: Intuitive interfaces for bundled offerings.
On-demand insurance Example: A car-sharing app provides insurance only during vehicle use.	Automation and process optimisation: Automatic policy activation and deactivation. Data analytics: Real-time risk analysis for dynamic pricing.
Dynamic pricing Example: A car-sharing app offers insurance premium adjustments based on driving behaviour.	Data analytics: Data analysis for defining pricing models. Flexible rating engine: Use of real-time data for pricing adjustments. Telematics and IoT integration: Connectivity with IoT devices and platforms.
Cross-selling through platforms	API integration: Seamless integration for cross-selling. User experience Design: Seamless cross-selling experience.
Subscription models Example: A user subscribes to a monthly car rental service that includes insurance.	Digital platforms and core systems: Support for recurring billing and customer management. Automation and process optimisation: Automated billing and notifications.
Contextual insurance Example: Short-term injury insurance tailored for high-risk activities offered during adventure sports.	API integration: Real-time policy issuance during events. User experience (UX) and user interface (UI) design: Seamless purchase experience during events.
Embedded in products offered by financial institutions Example: Credit cards with complimentary travel insurance, personal loans with built-in loan protection, and mortgage products with life insurance.	API integration: Seamless integration with financial systems. Robust data management & security: Secure data sharing and compliance management.

Source: Created according to the text: From Point of Sale to Point of Protection: The Journey of Embedded Insurance, September 2023, <https://blog.adacta-fintech.com/embedded-insurance>

Further on, we will provide some basic statistics on the prevalence of the concept of embedded insurance and on the future development of this concept.⁵⁴³ According to research study by Drača et al. (2024), the vast majority of respondents (93%) in this research (insurance company executives and senior management from IT and business operations) believe that in the next short-term period of 5 years there will be significant or moderate growth in the field of embedded insurance. Also, 94% of respondents believe that embedded insurance will play an important or critical role in setting their business and digital strategies in the future. Nineteen per cent of companies have a complete implementation of the embedded insurance concept, while 55% of respondents have a moderate representation of embedded insurance in their business model. According to the answer of the respondents, the key reasons for considering the introduction of the concept of embedded insurance in the business models of insurance companies are as follows (listed in order of importance): enhance customer experience, increase revenue, extended market reach, access untapped market segments, defend market share from new entrants, foster innovation, and others. Key business partners for embedded insurance come from the following industries: financial institutions, health and wellness platforms/providers, automobile industry, travel industry, e-commerce platforms, electronic retailers, etc. The basic challenges in the future development and implementation of the embedded insurance concept can be grouped into three layers: the first layer relates to data privacy and regulatory compliance; the second layer includes the IT model integration, compatibility of various devices and systems, the prevention of fraud; the third layer refers to the need to the increase of consumer awareness of embedded insurance and improvement of marketing perception of this concept.

⁵⁴³ Drača, D., Plavec, S., Vukobrat, I., & Tomšič, A. (2024). *State of Embedded Insurance 2024, Current Adoption and Future Perspectives of Embedded Insurance across Insurance organizations, Europe*. Adacta.

Chapter 19.

THE USAGE OF MACHINE LEARNING APPLICATIONS AND AI AGENTS IN THE INSURANCE INDUSTRY

In the 17th century, the mathematicians Blaise Pascal and Pierre de Fermat used an old pyramid of numbers to prove that mathematical probability could be determined⁵⁴⁴. This triggered a revolution in the development of probability theories, and mathematicians all over Europe cooperated and applied their findings to calculate life expectancy. Since the 18th century, building insurance as a business has begun, and the logic of calculation has proved to be an almost unbeatable business idea. Through the years, trade and emigration became the two most important facilitators for creating a global insurance network. Through subsequent historical movements, traditional insurance and insurance agents have been exposed to various challenges. For example, in the 20th century, large catastrophes such as the San Francisco Earthquake in 1906, Hurricane Betsy in 1965, and the attack on the World Trade Center in 2001 brought new challenges to the insurance industry. It had to cope with unexpected and enormous losses.

However, challenges came from other sources as well, including economic crises, floating exchange rates, and fluctuating interest rates, which caused even greater losses than the worst insured catastrophes. Surprisingly, the insurance industry has proven remarkably resilient to all these challenges. A long history of prudent reserving and risk awareness had taught insurers to act cautiously. The logical sequel to constant efforts to improve the accuracy of risk prediction was the engagement of automated intelligent models. As an automated process, artificially intelligent machines can recognise patterns of behaviour, adapt their responses to suit specific scenarios, or even influence changes within them.

Artificial Intelligence (AI) can be categorised based on a machine's ability to use past experiences to predict future decisions, as well as its capacity for memory and self-awareness. Machine Learning (ML), as a part of AI systems, uses past experiences and benefits from limited memory to predict decisions. ML has become so widespread that there are countless examples of its everyday use, including its application in insurance.

⁵⁴⁴ Saucedo, A. Jr. (2019). Pascal's Triangle, Pascal's Pyramid, and the Trinomial Triangle. *Electronic Theses, Projects, and Dissertations*, 855. <https://scholarworks.lib.csusb.edu/etd/855>.

1. TRADITIONAL DAMAGE ESTIMATION

Assessment of risk and potential loss is a key segment of the insurance industry.⁵⁴⁵ Therefore, in insurance practice, traditional damage assessment plays a crucial role. It involves directly hiring experts to evaluate the damage, collect physical documentation, and conduct expert analyses. This approach has been developed and standardised within insurance companies over decades. The process typically begins with a damage report filed by the policyholder, followed by the collection of documents such as police or incident reports, photographs of the damage site, witness statements, and invoices for completed repairs or property replacements. After that, an authorised appraiser or an expert hired by the insurance company visits the site to perform the physical damage assessment. Depending on the type of insurance, the appraiser may use additional instruments or consult independent experts.⁵⁴⁶

Although this method has provided a satisfactory basis for determining compensation in practice, numerous limitations have emerged over time. Traditional models are characterised by a high dependence on human factors, which can lead to subjective assessments and varying interpretations of the same evidence. Additionally, the entire procedure is often time-consuming, as it involves scheduling field assessments, processing paper documentation, and navigating multiple phases of approval. Errors in assessment or administration can result in extended payout timelines, directly impacting client satisfaction and the insurance company's reputation.⁵⁴⁷

These very challenges have opened the door for the application of modern technologies – especially artificial intelligence and machine learning – to accelerate, standardise, and objectify the damage assessment process.

2. MACHINE LEARNING INVOLVEMENT IN DAMAGE ASSESSMENT

Machine learning is a branch of artificial intelligence that enables computers to learn automatically from data and improve their performance without being explicitly programmed. The core of machine learning lies in identifying patterns,

⁵⁴⁵ Rejda, G. E., & McNamara, M. J. (2017). *Principles of Risk Management and Insurance*, 13th ed., Pearson Education.

⁵⁴⁶ Feng, R. (2023). Traditional Insurance. In: *Decentralized Insurance*. Springer Actuarial. Springer, Cham. https://doi.org/10.1007/978-3-031-29559-1_4

⁵⁴⁷ Abraham, K. S., & Schwarcz, D. (2022). The limits of regulation by insurance. *Indiana Law Journal*, 98(1), Article 5.

recognising trends, and making predictions based on historical data. This makes it particularly suitable for sectors that handle large volumes of both structured and unstructured information, such as the insurance industry.⁵⁴⁸

Machine Learning - the Leading Technique of Artificial Intelligence

Several important technologies contribute to intelligent insurance processes, including machine learning, deep learning, natural language processing, automation/robotics, and artificial senses, with machine vision, enabled through cameras and similar devices, being one of the most commonly used⁵⁴⁹.

Machine Learning (ML) is a process in which machines improve their responses based on structured datasets, large-scale data (big data), and continuous feedback from both humans and algorithms. **Deep learning**, which uses neural networks, is often considered a more advanced form of ML because it learns through representation and can effectively handle unstructured data.

The main types of machine learning include:

- Supervised learning
- Unsupervised learning
- Reinforcement learning

Natural Language Processing (NLP) is a linguistic tool within AI that enables machines to read, interpret, and process human language. It allows for the conversion of spoken or written language into computer-readable input⁵⁵⁰.

Common applications of NLP include:

- Understanding natural languages (e.g., Serbian, English, Italian, German, Hindi)
- Machine translation (e.g., Google Translate)
- Personal assistants (e.g., Siri, Google Assistant, Cortana, Alexa)
- Typo correction (spell checkers)
- Spam detection (filtering unwanted emails)

Automation and Robotics focus on improving productivity and process efficiency by enabling machines to perform monotonous and repetitive tasks,

⁵⁴⁸ Kelleher, J. D., Mac Namee, B., & D'arcy, A. (2020). *Fundamentals of machine learning for predictive data analytics: algorithms, worked examples, and case studies*. MIT Press.

⁵⁴⁹ Lucci, S., Musa, S. M., & Kopec, D. (2022). *Artificial intelligence in the 21st century*. Mercury learning and information.

⁵⁵⁰ Khan, A. A., Laghari, A. A., & Awan, S. A. (2021). Machine learning in computer vision: A review. *EAI Endorsed Transactions on Scalable Information Systems*, 8(32).

often resulting in significant cost savings. Many organizations integrate machine learning, neural networks, and graph-based technologies into automation and robotics to enhance functionality and decision-making. Using so-called CAPTCHA technology, such automation can also help prevent fraud during online financial transactions. Programmers develop robotic automation processes to handle large-scale repetitive tasks, which can be adapted to changing circumstances.

Machine Senses – such as artificial or computerised vision – allow machines to detect and analyse visual information. This process involves using cameras to capture images, converting analogue visuals into digital data, and processing that data through digital signal processing (DSP). The resulting information is then sent to a computer for further interpretation. In machine (or computer/ artificial) vision, two vital aspects are:

- Sensitivity – the ability to perceive light impulses and low-intensity signals
- Resolution – the level of image clarity or the extent to which a machine can distinguish between objects

Machine vision can be used in signature verification, pattern recognition, facial and object recognition, medical image analysis, and similar types of applications. In modern insurance, the above-mentioned techniques are primarily used to enhance the claims handling process in the following areas: claims settlement automation, risk prevention, and fraud detection.⁵⁵¹ These applications are particularly significant in material insurance, where data is more readily available, measurable, and often visually represented. Compared to life insurance, which relies more on long-term biometric and demographic data, material insurance provides more concrete inputs for machine processing, such as photographs, sensor data, damage documentation, and technical reports.

Machine Vision – Leader in Image Recognition and Processing

Machine vision focuses on the use of visualization systems in various applications, particularly in production and quality control within industry, as well as in insurance, where it helps detect changes in the condition of objects or scenarios that could lead to damage. Machine vision involves specialised hardware and software for the collection, processing, and analysis of images to enable automated inspection and decision-making. These systems are designed

⁵⁵¹ Frees, E. W., Derrig, R. A., & Meyers, G. (eds.). (2014). *Predictive modelling applications in actuarial science*, Vol. 1, Cambridge University Press.

to perform specific tasks and are often optimized for speed, accuracy, and robustness in different environments.

Computer vision, a broader field, encompasses the study and development of algorithms and techniques for extracting information and understanding from images and videos. Its primary goal is to enable computers to interpret and analyse visual data in a way that mimics human perception. Computer vision algorithms are widely applied in fields such as robotics, autonomous vehicles, augmented reality, medical imaging, and a variety of industrial applications.⁵⁵²

Machine vision is a transformative technology that merges computer science and image processing to enable automated visual inspection and analysis across different industries and sectors of the economy. It allows machines to replace – or even surpass – human visual abilities by analyzing images through computer systems using advanced algorithms for image processing and pattern recognition. In this way, computer systems are empowered to understand and interpret the contents of visual data.

A typical machine vision system includes image acquisition devices, processing algorithms, and decision-making components. Key elements are a camera, a main computer, frame capture hardware, an image processor, a lighting device, an image display, and a control mechanism – all working together to perform automated visual inspections. The camera captures visual input, while the lighting device ensures proper illumination. The main computer acts as the central processing unit, the frame capture hardware digitises and transfers image data, and the image processor analyses and interprets the visual information. The image display provides visual feedback, while the control mechanism manages motion control and system coordination. Together, these components form the core of a machine vision system, enabling effective image acquisition, processing of visual data, and meaningful output through automated analysis.

Automated Claim Processing

Traditional claim processing for damage compensation often involves manual document handling, client communication, and physical damage assessment – all of which are time-consuming and require significant resources. Machine learning, when combined with NLP and machine sensing techniques, enables the automation of claim classification, documentation validation, and even damage

⁵⁵² Mahadevkar, S. V., Khemani, B., Patil, S., Kotecha, K., Vora, D. R., Abraham, A., & Gabralla, L. A. (2022). A review on machine learning styles in computer vision—techniques and future directions. *IEEE Access*, 10, 107293-107329.

amount estimation based on historical data and comparable cases. Supervised learning algorithms are commonly used to identify relevant patterns and predict final decisions regarding compensation.⁵⁵³

Insurance companies use so-called Straight-Through Processing (STP) systems, which allow a large percentage of standardised and low-risk claims to be resolved entirely without human intervention. As a result, processing time is significantly reduced, and the overall user experience is greatly enhanced.⁵⁵⁴

An additional advantage of these systems is their ability to continuously learn – the more data the system processes, the more accurate its predictions become. Models are trained on thousands of past claims, learning to distinguish between valid and suspicious reports, as well as to recognise variations in damage amounts depending on factors as the type of incident, location, time, and the nature of the insured property.

AI agents and Chatbots. Interacting with a live customer service representative can often be lengthy and stressful for the client. For companies, it usually involves high costs, complex management, and significant human resource allocation.

One increasingly popular solution is the use of AI-powered chatbots. These bots are programmed with algorithms that allow them to respond to frequently asked questions, process requests, track claims and even handle incoming calls. Advanced bots can handle unforeseen scenarios and respond naturally, thanks to Natural Language Processing (NLP), which helps them understand and generate human-like language.

Modern chatbots do not require strictly formatted input (e.g., yes/no questions) and are capable of answering complex queries that demand detailed responses. If a chatbot receives a low rating for an answer, it can identify the mistake, learn from it, and adjust its future responses, constantly improving with each interaction. This learning ability ultimately leads to higher client satisfaction.⁵⁵⁵

⁵⁵³ Rawat, S., Rawat, A., Kumar, D., & Sabitha, A. S. (2021). Application of machine learning and data visualization techniques for decision support in the insurance sector. *International Journal of Information Management Data Insights*, 1(2), 100012.

⁵⁵⁴ Shreedharan, K. K. (2025). *Automated Claims Processing in Guidewire Claim Center: Enhancing Efficiency and Accuracy in the Insurance Industry*. Available at SSRN: <https://ssrn.com/abstract=5143235> or <http://dx.doi.org/10.2139/ssrn.5143235>

⁵⁵⁵ Suhaili, S. M., Salim, N., & Jambli, M. N. (2021). Service chatbots: A systematic review. *Expert Systems with Applications*, 184, 115461.

Risk Prevention

Risk prevention in insurance is a proactive approach focused on identifying, analysing, and managing potential threats that could lead to the occurrence of damage. Traditionally, this process relied on historical statistics, expert assessments, and generalised risk factors such as geographic location, the age of the insured property, or a history of past claims. However, with the development of machine learning, which incorporates both linear and nonlinear statistical methods, the capabilities for prediction and risk prevention have significantly advanced. Complex patterns and correlations, often invisible to human analysts, can now be automatically detected and leveraged.

Machine learning models enable insurance companies to identify high-risk clients, properties, and scenarios from large volumes of data even before a damage event occurs. By analysing past claim data, client behaviour, geographic conditions, weather forecast, property characteristics, or driving habits (in the case of car insurance), ML systems can accurately predict the likelihood of future damage. For instance, in property insurance, integrating data from meteorological sources, IoT sensors, and claims histories allows for the prediction of risks such as flooding, fire, or water pipe bursts.⁵⁵⁶

In car insurance, telematics and GPS tracking technologies collect real-time data on driving behaviour, including speed, sudden braking, movement patterns, and mobile phone use while driving. These machine learning tools – already embedded in modern navigation systems – have enhanced route optimization and overall road safety. It is now possible to use smart navigation software on our digital devices⁵⁵⁷. This data is analysed to detect risky driving behaviours, enabling insurers to offer personalised premiums and preventive recommendations. This approach underpins Usage-Based Insurance (UBI) models, which reward safe driving with lower premiums and help reduce the frequency and severity of claims.⁵⁵⁸

⁵⁵⁶ Blrier-Wong, C., Cossette, H., Lamontagne, L., & Marceau, E. (2020). Machine learning in P&C insurance: A review for pricing and reserving. *Risks*, 9(1), 4.

⁵⁵⁷ Holzinger, A., Weippl, E., Tjoa, A. M., & Kieseberg, P. (2021). Digital transformation for sustainable development goals (SDGs) - A security, safety and privacy perspective on AI. In: *International cross-domain conference for machine learning and knowledge extraction*. Cham: Springer International Publishing, pp. 1-20.

⁵⁵⁸ Hanafy, M., & Ming, R. (2021). Machine learning approaches for auto insurance big data. *Risks*, 9(2), 42.

In commercial property insurance, machine learning is used to develop dynamic risk models, for example, for facilities with pressurised equipment or warehouses storing hazardous materials. These models analyse data such as equipment failure frequency, machine condition, weather patterns, and employee behaviour, enabling timely intervention and accident prevention. Additionally, machine learning models not only identify risks but also allow for the simulation of various scenarios, helping managers make more informed, real-time decisions.⁵⁵⁹

The application of machine learning in risk prevention not only contributes to a reduction in the number of undesirable events but also improves the operational efficiency of insurance companies and strengthens client trust through greater transparency. In the coming years, ML models are expected to become more deeply integrated with smart devices, sensors, and drones that collect real-time data from the environment. This approach will enable insurance companies to detect risky situations in advance and intervene before damage occurs.

Fraud Detection

Fraud detection is one of the most critical challenges affecting the sustainability and profitability of insurance companies. According to the International Coalition Against Insurance Fraud, more than 10% of all claims submitted globally contain elements of fraud. This results in multi-million-dollar losses for insurance companies and indirectly impacts all policyholders through increased premiums and delayed compensation.⁵⁶⁰

Traditional fraud detection methods in insurance rely on manual checks, standardised control lists, and employee experience. However, these approaches are often reactive – activated only after fraud has occurred – and lack the capacity to predict or prevent fraudulent activity in advance. They are also time-consuming and inefficient, particularly in complex or high-volume scenarios. The introduction of machine learning has marked a significant shift in this field, enabling fraud detection in advance – automatically, quickly, and in real time – by analysing large volumes of data and identifying specific behaviour patterns.

Machine learning uses classification algorithms and anomaly detection techniques to flag claims that deviate from typical behaviour patterns. For

⁵⁵⁹ Sood, K., Balusamy, B., Grima, S., & Marano, P. (eds.) (2022). *Big data analytics in the insurance market*. Emerald Publishing Limited.

⁵⁶⁰ Coalition Against Insurance Fraud (2022). *Insurance Fraud Statistics*. Available at <https://insurancefraud.org/wp-content/uploads/The-Impact-of-Insurance-Fraud-on-the-U.S.-Economy-Report-2022-8.26.2022-1.pdf>

example, claims submitted immediately after policy activation, frequent reports of similar damages, repeated claims by the same user, or illogical combinations of factors (such as time, location, and type of damage) can all indicate potential fraud. Such cases are automatically flagged for further analysis.

The most commonly used algorithms for fraud detection include Logistic Regression, Random Forest, XGBoost, Support Vector Machines (SVM), and more advanced neural networks, particularly for analyzing unstructured data such as images, video recordings, and textual statements. Recently, supervised learning techniques designed to handle imbalanced datasets have gained popularity, as fraudulent claims occur far less frequently than valid ones, making model training more challenging.⁵⁶¹

In the area of material insurance – especially car and property insurance – common cases of fraud include staged car accidents, duplicate damage reports, inflated property valuations, or the use of fake repairers and appraisers. In such situations, machine learning can analyse a user's profile, communication history, document samples, and even weather conditions at the time of the event, helping to build a comprehensive risk profile.⁵⁶²

In developing insurance markets, such as Serbia, the application of ML in fraud detection is still in its early stages. However, the growing trend of digitalisation and the increasing volume of data indicate a clear need for implementing such systems in the future. Insurance companies that have already adopted ML tools report notable improvements, including shorter processing times, a higher rate of fraud detection, and better allocation of human resources, allowing staff to focus on more complex cases.⁵⁶³

In conclusion, machine learning has the potential to significantly enhance fraud detection processes in insurance, particularly in the context of increasingly complex claims and the growing amount of available data. Unlike traditional methods, which are mostly reactive, modern algorithms enable a proactive approach, identifying suspicious patterns early in the claim process. This not only

⁵⁶¹ Kaswan, K. S., Dhatteerwal, J. S., Sharma, H., & Sood, K. (2022). Big data in insurance innovation. *Big Data: A game changer for insurance industry*, pp. 117-136.

⁵⁶² Pérez-Zarate, S. A., Corzo-García, D., Pro-Martín, J. L., Álvarez-García, J. A., Martínez-del-Amor, M. A., & Fernández-Cabrera, D. (2024). Automated Car Damage Assessment Using Computer Vision: Insurance Company Use Case. *Applied Sciences*, 14(20), 9560.

⁵⁶³ Pavlović, B., & Minić Pavlović, V. (2022). Snagom podataka do osiguranja budućnosti. *Proceedings SORS 2022*, Sarajevo, pp. 153-182.

improves detection accuracy but also optimises resource use within insurance companies. The introduction of such technologies represents a logical step in the digital transformation of the insurance sector, offering added value through more efficient risk management, faster decision-making, and increased client trust.

3. TYPES OF INSURANCE SUITABLE FOR THE APPLICATION OF MACHINE LEARNING

Machine learning (ML) finds some of its most practical applications in the insurance sector, particularly in areas where processes can be quantified and data can be consistently standardised and collected. In this regard, the most suitable types of insurance for implementing ML technologies are those dealing with material damage. These lines of insurance are characterized by large volumes of both structured and unstructured data, a high frequency of claims, and strong potential for automated information processing.

Car insurance is one of the first segments of the insurance industry where machine learning has been widely applied. This type of insurance involves extensive data collection related to users, vehicles, locations, weather conditions, and the type and severity of damage caused in traffic accidents. Using deep learning algorithms, it is now possible to analyse photographs of damage and automatically classify the type and severity of the loss. Additionally, telematics data (such as speed, sudden braking, and driving behaviour) can be used to create risk profiles and determine personalised premiums (usage-based insurance). Insurance companies also use ML to streamline claims settlements, automate approvals for simple claims, and detect potential fraud. Thanks to digital platforms and mobile apps, clients can upload damage photographs themselves, while models trained on thousands of similar cases provide fast and reliable assessments of necessary repairs and compensation amounts. This approach significantly reduces processing time, improves customer satisfaction, and enables more efficient resource allocation within companies.⁵⁶⁴

Property insurance is another key area, covering residential buildings, business premises, and other real estate. This type of insurance protects against damages caused by fire, floods, lightning, storms, burglary, and other risks. Machine learning is used in this field to predict the probability of damaging events based on factors such as property location, damage history, building type, construction year, and climate patterns. Based on this, insurers can more accurately assess risk

⁵⁶⁴ Abdelhadi, S., Elbahnasy, K., & Abdelsalam, M. (2020). A proposed model to predict auto insurance claims using machine learning techniques. *Journal of Theoretical and Applied Information Technology*, 98(22), pp. 3428-3437.

and tailor coverage conditions for each individual client. Moreover, integrating ML with data from IoT devices – such as humidity, smoke, temperature, and motion sensors – enables timely alerts for potential incidents. For example, in the case of a flood, automated systems can detect a sudden rise in water levels and trigger early warnings and preventive actions, significantly reducing damage and insurer costs.⁵⁶⁵ Visual inspections using drones further enhance the accuracy of damage assessments after catastrophes, while unstructured data (such as photographs and video recordings) can be processed in real time using advanced ML models.

In the commercial property insurance sector, the use of machine learning is becoming increasingly important due to the complexity of insured assets and the high potential for loss. Industrial facilities, manufacturing lines, warehouses, and energy systems require constant monitoring and proactive risk mitigation. In this context, ML is used to analyse operational data, detect technical failures or equipment malfunctions, and assess human behaviour, helping to predict potential incidents.

Through predictive maintenance models, early signals of malfunction or inefficiency can be identified, reducing the risk of serious breakdowns or downtime. Furthermore, combining ML with sensor systems helps manage risks such as fire, chemical leaks, mechanical impacts, and other adverse events. Insurance companies are now receiving real-time data from insured sites, enabling dynamic premium pricing, more flexible coverage options, and faster responses when incidents occur.⁵⁶⁶

Thanks to data availability, high claim frequency, and the potential for full digitalisation, material damage insurance provides an ideal environment for the integration of machine learning. The benefits are evident not only in improved operational efficiency but also in enhanced customer experience and increased market competitiveness. While similar technologies are gradually being adopted in other branches of insurance, material insurance remains the leader in both the speed and depth of artificial intelligence adoption.

⁵⁶⁵ Arshad, B., Ogie, R., Barthelemy, J., Pradhan, B., Verstaeevel, N., & Perez, P. (2019). Computer vision and IoT-based sensors in flood monitoring and mapping: A systematic review. *Sensors*, 19(22), 5012.

⁵⁶⁶ Valli, L. N. (2024). Predictive Analytics Applications for Risk Mitigation across Industries; A review. *BULLET: Jurnal Multidisiplin Ilmu*, 3(4), pp. 542-553.

Life Insurance: Limitations of Machine Learning Application

Unlike insurance types related to material damage, where data is visual, quantitative, and often collected in real time, life insurance involves a fundamentally different risk structure. In this segment, risks are long-term, based on the probability of specific events occurring, and typically connected to biological, demographic, and statistical characteristics of individuals, such as age, sex, health status, family medical history, and lifestyle.⁵⁶⁷

Due to the nature of the data, the application of machine learning in life insurance is less widespread and technically more challenging. The data is often sensitive, unevenly distributed, and constrained by regulatory frameworks concerning privacy. Additionally, the frequency of events that serve as the basis for risk assessment is low, which makes it difficult to train accurate ML models. In life insurance, critical events such as death or the onset of serious illness, which trigger policy activation, occur relatively rarely compared to the total number of policyholders, especially over short time frames. For instance, a model that predicts 'no death' in 99% of cases may appear highly accurate but would fail to identify almost all critical cases, posing a serious problem for both insurance practice and health-related analytics.⁵⁶⁸

Nevertheless, certain areas within life insurance do allow for the selective application of ML techniques. These include health pattern analysis using electronic health records, premium model optimization, fraud detection, and market segmentation.

However, due to the limited availability of high-quality data and significant regulatory oversight, the adoption of machine learning in life insurance remains considerably slower than in material insurance. Effective claims processing in this domain requires a multidisciplinary approach – bringing together data scientists, actuaries, legal experts, and health analysts – to balance innovation with ethical standards and legal compliance.

⁵⁶⁷ Boodhun, N., & Jayabalan, M. (2018). Risk prediction in life insurance industry using supervised learning algorithms. *Complex & Intelligent Systems*, 4(2), pp. 145-154.

⁵⁶⁸ Luu, J., Borisenko, E., Przekop, V., Patil, A., Forrester, J. D., & Choi, J. (2024). Practical guide to building machine learning-based clinical prediction models using imbalanced datasets. *Trauma Surgery & Acute Care Open*, 9(1).

Machine Learning Applications by Data Type

Machine learning demonstrates diverse applications in insurance, depending on the type of available data – each format bringing its own technical challenges and unique potential. Visual data, such as photographs and video recordings, play a particularly important role in car and property insurance. Images of damaged vehicles, properties affected by natural disasters, or footage from surveillance cameras can be analysed using convolutional neural networks (CNNs), which recognise patterns, classify damage, and estimate its severity. In this way, video data processing enables the automation of damage assessment without the need for on-site inspection.⁵⁶⁹

Video recordings, increasingly used for monitoring business premises, warehouses, and industrial facilities, allow for dynamic analysis, including the recognition of atypical behaviour, accident dynamics, and the early detection of potentially damaging events. In such cases, deep learning models combine image processing with temporal analysis to detect behavioural shifts and emerging anomalies.⁵⁷⁰

On the other hand, IoT devices and sensor systems provide real-time quantitative data that supports proactive intervention and effective risk management. Sensors that measure temperature, smoke, humidity, pressure, vibration, and motion are widely used in commercial and industrial insurance. The collected data is continuously analysed by ML models to detect deviations from normal values and issue early warnings about threats such as fire, gas leaks, floods, or mechanical failures. This integration of technologies allows insurance companies not only to respond quickly but also to offer dynamic premium models based on actual risk exposure.

Different types of data require different ML techniques, ranging from classification and regression for numerical and time series data to deep learning and unstructured data processing for visual and textual information. This versatility makes machine learning a key enabler in the modernization of damage assessment and risk management across the insurance industry.

⁵⁶⁹ Artan, C. T., & Kaya, T. (2020). Car damage analysis for insurance market using convolutional neural networks In: *Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making: Proceedings of the INFUS 2019 Conference*, Springer International Publishing, pp. 313-321.

⁵⁷⁰ Muddasir, N. M., Siddiqi, M., Dechamma, M. L., Ayesha, B. B., & Jahnavi, H. S. (2025). To save life: A car crash detection system using deep learning. In: *Recent Trends in Healthcare Innovation*, CRC Press, pp. 26-32.

4. DAMAGE ASSESSMENT AUTOMATION: CLASSIFICATION AND PREDICTION

One of the most significant contributions of machine learning in the insurance industry is the automation of damage assessment through predictive models based on supervised learning. These models are trained on previously labelled datasets with known outcomes, such as compensation amounts or damage classifications, allowing algorithms to learn the relationships between input features and output results.⁵⁷¹

In automated damage assessment, machine learning typically relies on two main types of models:

1. Classification models: These categorize claims based on predefined classes. For example, damage can be classified into levels such as 'minor', 'moderate', or 'severe'.
2. Regression models: These predict the estimated cost of damage, typically in monetary value (e.g., how much needs to be paid out).⁵⁷²

To make these models work, different types of data are used. This includes structured data, which is organised and easy to analyse (such as the type of damaged property, the age of a vehicle, the time of the damage, and prior damage history) and unstructured, more complex data (such as photographs and textual descriptions of damages), which require advanced processing techniques.

After preparing this data and selecting relevant features (a process called feature engineering), it is divided into three sets:

- Training set: Used to train the machine learning model to recognise patterns and make damage assessments.
- Validation set: Used to evaluate the model's accuracy and check its performance on new, unseen data, ensuring it does not overfit to the training set.
- Test set: A completely separate dataset to evaluate the model's final performance after optimization.⁵⁷³

⁵⁷¹ Abdulkadir, U. I., & Fernando, A. (2024). A Deep Learning Model for Insurance Claims Predictions. *Journal of Artificial Intelligence* (2579-0021), 6.

⁵⁷² Keita, Z. (2024). Classification in machine learning: An introduction. *Datacamp. Erişim*, 27.

⁵⁷³ Sahai, R., Al-Ataby, A., Assi, S., Jayabalan, M., Liatsis, P., Loy, C. K. & Kolivand, H. (2022). Insurance risk prediction using machine learning. In: *The International Conference on Data Science and Emerging Technologies*, Singapore: Springer Nature Singapore, pp. 419-433.

In this final phase, various metrics are used to assess the success of the model. A major advantage of using supervised learning for damage estimation is its repeatability and scalability – the ability to apply it to large volumes of data. Once trained on a large set of examples, the model can quickly and efficiently analyse thousands of new claims for damage assessment in real time.

5. TRADITIONAL VS. AI INSURANCE AGENTS

Traditional insurance agents have been fundamental to the insurance industry for centuries, with more than 80% of business traditionally handled by individual agents acting based on intuition.⁵⁷⁴ Today, insurance agents are strongly encouraged to educate themselves and to participate in advanced training programs to meet the growing demands of the digital market. There is also a continual need to improve product knowledge, which suggests that more training programs should be organized for all general insurance companies. These training programs play a crucial role in raising the competency and professionalism within the general insurance sector.

The training program requires a strong foundational knowledge of general insurance, as well as an understanding of new digital products. Since the 2000s, training methods for insurance agents have gained increasing popularity⁵⁷⁵ and have become one of the primary HR responsibilities for insurance companies. To evaluate the effectiveness of these training programs, categories of measurement, according to Kirkpatrick's model⁵⁷⁶, can include reactions, learning, behaviour, and results.

AI insurance agents are technology-driven assistants that use tools such as machine learning, deep learning, computer vision, image recognition, and processing to analyse damage and make risk predictions⁵⁷⁷. Instead of manually inspecting and assessing damage, AI systems can now process images uploaded

⁵⁷⁴ Acharya, M., & Hebbar, C. K. (2023). A Review of Traditional Advisors of Life Insurance and Bancassurance Channel. *The Journal of Insurance Institute of India*, 10 (III), pp. 89-102.

⁵⁷⁵ Hedge, J. W., Borman, W. C., & Birkeland, S. A. (2001). History and Development of Multisource Feedback as a Methodology. In: *Handbook of Multisource Feedback*, San Francisco, CA: Jossey-Bass, pp. 15-32.

⁵⁷⁶ Alliger, G. M., & Janak, E. A. (1989), Kirkpatrick's levels of training criteria: Thirty years later. *Personnel Psychology*, 42, pp. 331-342.

⁵⁷⁷ Daruvuri, V. et al. (2025). The Technical Implementation of Agentic AI in Modern Insurance Operations. *International Journal of Computer Engineering & Technology*, 16, pp. 2035-2053.

by claimants, identifying and categorising damage with high speed and accuracy. This automated process not only improves efficiency but also reduces human error. Studies have shown that AI insurance agents make fewer errors compared to traditional ones. The advantages of AI agents are as follows:

- AI agents offer significant cost-saving opportunities for companies. By automating the claims evaluation process, insurers can reduce labour costs. Additionally, the increased efficiency of AI-driven systems minimises the time spent on claim processing, further lowering operational costs.
- One of the most impressive advantages of AI-powered damage assessment is its unmatched speed and efficiency. AI systems can process thousands of images in just a minute.
- Improved customer experience results from a faster and more efficient claims process. Clients no longer have to wait weeks for a claim to be reviewed and settled. With AI-powered systems, they can receive instant feedback, faster resolutions, and quicker settlements, which improves satisfaction and builds trust between the insurer and the customer.
- Consistency, accuracy and objectivity of AI agents ensure more reliable results. Human agents may interpret damage differently based on their experience, personal judgment, or external factors, leading to discrepancies in claims evaluations. In contrast, AI models are trained on diverse datasets, enabling them to recognise damage under various conditions with a high degree of accuracy.
- Data-driven decision-making brings significant benefits. By analyzing big data, insurers gain valuable insights that aid in decision-making, risk assessments, and fraud detection efforts.

In summary, AI insurance agents offer numerous advantages, including significant cost savings, rapid and efficient big data analysis, and more consistent and accurate results. These benefits collectively lead to better decision-making capabilities and, ultimately, an improved customer experience.

CHALLENGES IN APPLYING MACHINE LEARNING FOR PREDICTIVE MODELLING

The rapid evolution of digital financial transactions and insurance operations has significantly increased the reliance on machine learning for predictive modelling. The application of sophisticated machine learning techniques, including feature transformation, data balancing, and model optimisation, enabled the detection of anomalies in financial systems and claim predictions in the insurance sector. Assuming that artificial intelligence (AI) can contribute to the improvement of the actuarial profession in the Republic of Srpska, this chapter of the monograph will, along with discussing its application in predicting claims and assessing insurance risk, also present the prerequisites that artificial intelligence needs to fulfil to be utilised in the insurance market of the Republic of Srpska while following ethical standards and actuarial practice guidelines. Our aim is to explore the potential impacts of artificial intelligence on the actuarial profession, analysing how actuaries can use AI tools and techniques to enhance their work and competencies and, thus, provide benefits to policyholders, insurers, and the development of this profession.

1. FEATURES OF THE INSURANCE MARKET OF THE REPUBLIC OF SRPSKA

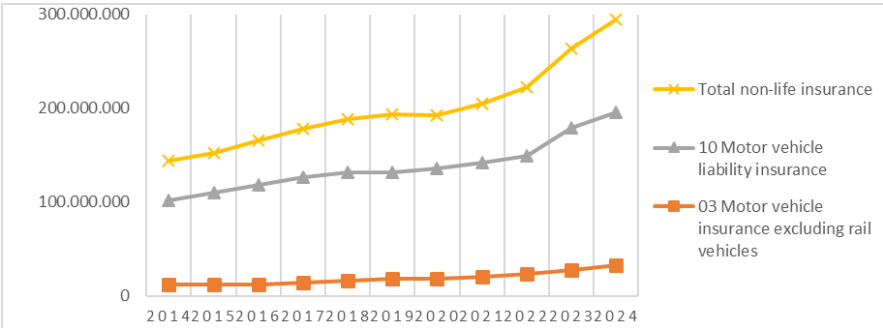
The insurance market in Bosnia and Herzegovina, like the state itself, is divided into two entities, each with its own supervisory body. In the Republic of Srpska, supervision of private insurance is performed by the Insurance Agency of the Republic of Srpska, established in 2006 under the provisions of the Law on Insurance Companies⁵⁷⁸. On the other hand, in the territory of the Federation of Bosnia and Herzegovina, the Insurance Supervision Agency of the Federation of Bosnia and Herzegovina has been operating since 2005 in accordance with the Law on Insurance Companies in Private Insurance⁵⁷⁹. Insurance companies register with one of the entities when establishing the company, and if they wish to expand their operations into the other entity, they must seek approval from the relevant supervisory authorities to conduct business activities in that entity.

⁵⁷⁸ Law on Insurance Companies, *Official Gazette of the Republic of Srpska*, No. 17/05, 01/06, 64/06, 74/10, 47/17 and 58/19.

⁵⁷⁹ Law on Insurance Companies in Private Insurance, *Official Gazette of the Federation of Bosnia and Herzegovina*, No. 24/05 and 36/10.

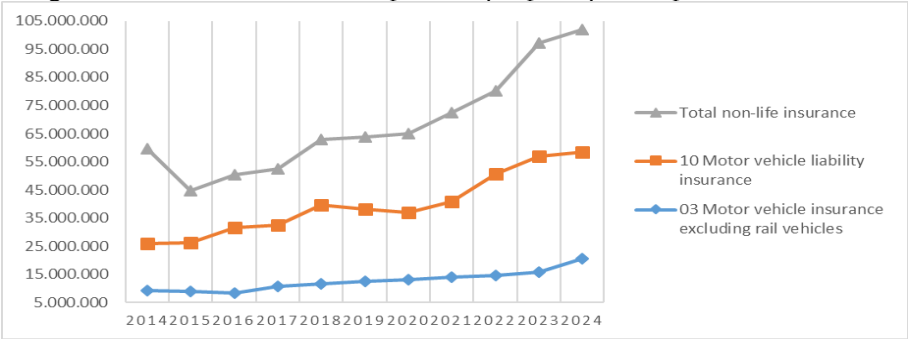
In 2024, 23 insurance companies operated in the insurance market of the Republic of Srpska, 14 of which were headquartered in the Republic of Srpska, while 9 were based in the Federation of Bosnia and Herzegovina and operated through their registered branches in the Republic of Srpska. In the Republic of Srpska insurance market, the total gross written premium for non-life insurance in 2024 amounted to BAM 294,583,748 (Figure 1), while the paid claims totalled BAM 102,075,429 (Figure 2). The car insurance premium (motor vehicle insurance excluding rail vehicles and motor vehicle liability insurance) accounted for approximately 77% of the total non-life insurance premium. These two types of insurance also accounted for 77% of the total paid claims in the Republic of Srpska market in 2024.

Figure 1. Non-life insurance premiums realised in the Republic of Srpska for the period 2014-2024



Source: Insurance Agency of the Republic of Srpska (2025)

Figure 2. Paid claims in the Republic of Srpska for the period 2014-2024



Source: Insurance Agency of the Republic of Srpska (2025)

Having presented the challenges in introducing innovative techniques in the Republic of Srpska insurance market, we will focus on motor vehicle liability Insurance and motor vehicle insurance, grouped under the term car insurance, in

the example presented at the end of this section. The regulations and practices related to tariff setting in these two types of insurance currently differ in the market. Insurance companies in motor vehicle insurance or casco insurance set their own premium tariffs. Motor vehicle liability insurance belongs to the category of compulsory insurance regulated by the Law on Compulsory Traffic Insurance⁵⁸⁰. Article 12 of the law stipulates that the Agency Management Board shall implement a standardised premium tariff and price list for motor vehicle liability insurance, which remains in force until 31st December 2026. Along with the premium tariff, the insurance company is also obligated to submit to the Agency the technical bases it uses for setting premium rates. According to the applicable premium tariff and the price list for motor vehicle liability insurance in the Republic of Srpska when setting premium rates established by the tariff, the following criteria (risk factors) are taken into account: the type and purpose of a vehicle, technical characteristics of a vehicle (such as engine power, load capacity, engine displacement, number of registered seats, and number of employees in the workshop), duration of the insurance, and past performance of the insured (bonus/malus).⁵⁸¹ Following the full liberalisation of the motor vehicle liability insurance market, insurance companies in the Republic of Srpska will be able to incorporate additional factors into their tariff calculations, such as those listed in the section on Car Insurance Claim Classification. When considering which factors to include in tariff calculations, it is important to note that under the current Traffic Law, insurance contracts for third-party liability cover not only the vehicle owner but also any person using the vehicle with the owner's consent. Thus, the policy is vehicle-based rather than driver-based, and the motor vehicle liability insurance policy is not limited to a single driver. This practice is also practised by most European countries. On the other hand, in the United States, insurance policies are typically linked to a driver, which may explain why the focus is on driver-related factors when determining tariff models. We believe that current insurance regulations regarding the introduction of new products and amendments to the existing ones are necessary since liberalisation in setting prices could lead to destructive competition among insurers due to intense competition for market share and a decrease in premiums, threatening the solvency of insurance companies. Therefore, the liberalisation process should be handled carefully. Before introducing a new product or making amendments to

⁵⁸⁰ Law on Compulsory Motor Vehicle Insurance, *Official Gazette of the Republic of Srpska*, No. 82/15, 78/20 and 1/24.

⁵⁸¹ Decision on the Standardised Premium Tariff and Price List for Motor Vehicle Liability Insurance in the Republic of Srpska, *Official Gazette of the Republic of Srpska*, No. 8/24, 91/24.

the existing one, insurance companies operating in the Republic of Srpska need to ensure the necessary criteria for effective risk management and control.⁵⁸²

In the following section, we will address the criteria for applying artificial intelligence (AI) concerning the future of the actuarial profession in the Republic of Srpska from the perspective of professional standards, the need for education in machine learning principles, and the provision of necessary data.

2. ACTUARIAL ASPECTS OF APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE INSURANCE MARKET OF THE REPUBLIC OF SRPSKA

Considering the scope of the authorised actuaries' activities, their responsibilities, and the current regulations that govern them is vital in terms of analysing the assumptions, limitations, and risks related to the introduction of AI-based models in actuarial practice. Therefore, in this section, we will discuss some of the regulations that govern actuaries' practice in the Republic of Srpska. The Decision on the Content of the Opinion of a Certified Actuary⁵⁸³ (Article 2) defines that the company is obliged to notify the Insurance Agency of the Republic of Srpska within 15 days that a new product has been adopted or has undergone amendments or supplements. Although the Insurance Agency of the Republic of Srpska does not give prior approval for the introduction of products pursuant to Article 13 of the Insurance Companies Act, it can limit the scope of insurance activities performed by a certain insurance company for a certain period if it is necessary to protect the financial capacity of the company. During the process of tariff control, the Insurance Agency used to require changes to the provisions related to discounts if they are not tied to actual and measurable risk characteristics that are the subject of insurance, and whose effects cannot be quantified or controlled in accordance with actuarial principles and methods. Article 54 of the Insurance Act defines that if the Insurance Agency of the Republic of Srpska determines that an insurance company is violating the rules of risk management and protection of policyholders, it can instruct the insurance company to change the types of insurance activities, suspend the application or amend the insurance terms and premiums, and take other measures necessary to improve risk management procedures.

⁵⁸² Mitrašević, M. (2016). Aktuarske odrednice razvoja proizvoda osiguranja. *Jahorina Business Forum*, 2016(1), pp. 445-459.

⁵⁸³ Decision on the Content of the Opinion of the Certified Actuary, *Official Gazette of the Republic of Srpska*, No. 15/07.

The absence of regulations defining the principles for managing artificial intelligence and proper governance of operational risks related to digital security in the insurance market is currently, to some extent, compensated by the regulations in the areas of risk management, premium calculation, technical reserves, and capital adequacy. However, having recognised the potential of artificial intelligence for enhancing the actuarial profession in the Republic of Srpska and the risks associated with its application, outlined by Preez et al.⁵⁸⁴ as well, regulating this area should become one of the key priorities in the Republic of Srpska insurance market.

Since there are no regulations directly defining the application of artificial intelligence in the Republic of Srpska, we will analyse the regulations in force in the European Union to conclude the potential risks posed by the lack of regulation in this area. In the European Union, the AI Act has been in force since July 2024, establishing a set of requirements that providers and users of high-risk AI systems are obliged to comply with. In the insurance sector, this law categorises AI systems used for risk assessment and pricing of individuals in life and health insurance as high-risk systems. The AI Act has introduced additional requirements for providers of high-risk AI systems.⁵⁸⁵ The European Insurance and Occupational Pensions Authority (EIOPA) published a report in 2021 by the Consultative Expert Group on Digital Ethics, which outlines six principles for AI governance: proportionality, fairness and non-discrimination, transparency and explainability, human oversight, data management and record-keeping, and robustness and performance. Nevertheless, we will mostly focus on explainability, i.e. transparency, which implies the degree to which actuaries can understand and explain the decisions and predictions made by AI systems. Insurance companies should be able to explain to regulators and auditors the principles underlying their tariff models, and consumers should be informed about the key factors influencing the size of insurance premiums, enabling them to make informed decisions, adjust their choices, and accept the consequences. To achieve this, a high level of transparency and explainability is necessary for the systems, models, and data used. On the other hand, there may be fewer requirements for transparency in the case of fraud detection systems since fraud will always need to be proven. The goal of fraud detection systems is to provide

⁵⁸⁴ du Preez, V., et al. (2024). From bias to black boxes: Understanding and managing the risks of AI – an actuarial perspective. *British Actuarial Journal*, 29, e6. <https://doi.org/10.1017/S1357321724000060>

⁵⁸⁵ European Parliament (2024). Artificial Intelligence Act: MEPs adopt landmark law. *Press release*, <https://www.europarl.europa.eu/news/en/press-room/20240308IPR19015/artificial-intelligence-act-meps-adopt-landmark-law>

suggestions to the insurance company on how to prioritise certain actions and, accordingly, increase efficiency in internal processes.⁵⁸⁶

In addition to the lack of regulations governing the field of artificial intelligence in the Republic of Srpska, a significant limitation in conducting the research at the time of writing this section was caused by the lack of publicly available relevant data on experiences regarding artificial intelligence applications. The report on the integration of the digital economy in the Western Balkans shows that in 2021, 7% of businesses in this area used big data (3.9% in Bosnia and Herzegovina), 16% used cloud services (7% in Bosnia and Herzegovina), and 3% used artificial intelligence (2% in Bosnia and Herzegovina), compared to businesses in the European Union, where the percentages amounted to 14%, 34%, and 8%, respectively. Furthermore, based on publicly available data, we still cannot conclude the extent of the use of artificial intelligence in insurance companies in the Republic of Srpska.⁵⁸⁷ According to our findings, experiences in applying artificial intelligence by certified actuaries in this market are mostly in form of ChatGPT as one of the large language models (LLMs). LLMs are a class of artificial intelligence models trained on large amounts of textual data and belong to the class of generative models. When using this tool, it is important to consider the research by Balona⁵⁸⁸ that practically demonstrated that ChatGPT often provided incorrect mathematical facts and was unreliable with Python coding. A similar conclusion was drawn when GitHub's Copilot was used for coding assistance. Therefore, the need for careful review and potential optimisation of the generated code was emphasised. In accordance with professional standards, holders of actuarial functions in the Republic of Srpska should consider the potential impacts that large language models can have on business operations and conduct a careful review of the obtained answers and the decisions made based on them.

As for transparency, a different approach to the application of artificial intelligence in insurance for obtaining results was presented during the webinar

⁵⁸⁶ European Insurance and Occupational Pensions Authority (2021). *Artificial intelligence governance principles: Towards ethical and trustworthy artificial intelligence in the European insurance sector*. Frankfurt am Main: EIOPA, <https://www.eiopa.europa.eu/system/files/2021-06/eiopa-ai-governance-principles-june-2021.pdf>

⁵⁸⁷ Regional Cooperation Council (2023). *Western Balkans Digital Economy and Society Index (WB DESI) 2022 Report*, <https://www.rcc.int/pubs/159/western-balkans-digital-economy-society-index-wb-desi-2022-report>

⁵⁸⁸ Balona, C. (2024). ActuaryGPT: Applications of large language models to insurance and actuarial work. *British Actuarial Journal*, 29, e15. <https://doi.org/10.1017/S1357321724000102>

titled Application of Artificial Intelligence in the Financial Sector of the Republic of Srpska, held on 25th March, 2025⁵⁸⁹ on the premises of the Research Centre of the Faculty of Business Economics, University of East Sarajevo. Miona Graorac, Senior Actuarial Consultant in the company Willis Towers Watson⁵⁹⁰, presented to the representatives of insurance companies a machine-led reserving algorithm developed by the company as part of its ResQ software. This approach is explained in more detail in the monograph published in 2024 by Mitrašević, Kočović, Koprivica, and Graorac.⁵⁹¹ Due to the fact that the software uses the methods that are widely accepted in actuarial practice in the Republic of Srpska, and since the model outputs are transparent, the use of this software is possible either without or with only minor amendments to the technical bases of insurance and the regulations governing the calculation of claim reserves in non-life insurance.

When applying artificial intelligence, insurance companies need to provide appropriate levels of supervision, adequate training for employees, define the tasks that need to be performed, as well as the persons responsible for performing AI-related tasks. It should be noted that the ability of insurance companies to adopt new technologies for insurance activities, pricing, and risk reduction depends on their ability to access sufficient, reliable, and high-quality external and/or internal data. According to our findings, a specific issue currently faced by domestic insurance companies is separate information systems for premium, financial accounting, and the information systems where claims are recorded; nevertheless, the link between those systems is not entirely automatised.⁵⁹² With the advancement of technology, insurers have been enabled to utilise new data sources. Wong et al. (2021) presented a review of the studies on telematics pricing as one of the emerging topics in actuarial science and practice, given that

⁵⁸⁹ University of East Sarajevo, Faculty of Business Economics (2025). *Webinar held on the topic: Application of artificial intelligence in the financial sector of the Republic of Srpska*, <http://www.fpe.ues.rs.ba/news/10043/257/odrzan-vebinar-na-temu-primjena-vjestacke-inteligencije-u-finansijskom-sektoru-republike-srpske.html>

⁵⁹⁰ Willis Towers Watson (n.d.). *Homepage*. <https://www.wtco.com>

⁵⁹¹ Mitrašević, M., Kočović, J., Koprivica M., & Graorac, M. (2024). Application of artificial intelligence in projecting claims within non-life insurance. In: *Transformation of the Economy with Artificial Intelligence: Perspectives, Challenges and Opportunities*, Mitrašević, M. et al. (eds.), Bijeljina: University of East Sarajevo, Faculty of Business Economics, pp. 36-54.

⁵⁹² Mitrašević, M. (2019). Obezbeđenje kvaliteta podataka kao ključni preduslov adekvatne procene obaveza osiguranja, *EkonBiz*, 19, pp. 292-302.

this type of data has only recently appeared.⁵⁹³ The ability of insurance companies to apply new data sources, analytical tools based on artificial intelligence and machine learning is influenced by legislation, regulations, and supervisory measures implemented to ensure safeguards against unfair discrimination, and support digital security. It is also important to note that rigorous data protection protocols within insurance institutions can safeguard policyholders' privacy and preserve the integrity and reputation of the insurer.⁵⁹⁴

In accordance with generally accepted standards of practice, actuaries have to ensure that models are fit for their intended purpose and free from material biases, which in the case of machine learning models can arise from their training data or the selected algorithm. Understanding the model provides actuaries with essential tools to efficiently debug models and identify potential issues in data processing or model training. Furthermore, understanding the model is crucial for detecting biases that may have various impacts on certain groups. By uncovering such inappropriate biases, actuaries can take corrective measures, mitigate discrimination, and support fairness in decision-making processes. As for applying artificial intelligence for setting insurance prices, regulators would need to develop a test for checking the models of insurance companies to determine whether they comply with the relevant standards.⁵⁹⁵

3. EMPIRICAL IMPLEMENTATION OF MACHINE LEARNING IN INSURANCE

This study focuses on two key implementations: credit card fraud detection and car insurance claim prediction, leveraging extensive datasets to construct robust predictive models that mitigate financial risks and optimise operational efficiency.

⁵⁹³ Blier-Wong, C., Cossette, H., Lamontagne, L., & Marceau, E. (2021). Machine learning in P&C insurance: A review for pricing and reserving. *Risks*, 9(4), 80. <https://doi.org/10.3390/risks9010004>

⁵⁹⁴ Tešić, N., & Kočović De Santo, M. (2024). Opportunities for the application of artificial intelligence in managing catastrophic risks. In: *Transformation of the Economy with Artificial Intelligence: Perspectives, Challenges and Opportunities*, Mitrašević, M. et al. (eds.), Bijeljina: University of East Sarajevo, Faculty of Business Economics.

⁵⁹⁵ Paunović, B., Tešić, N., & Kočović, J. (2019). Impact of Industrial Revolution 4.0 on insurance and its contribution to sustainable development. In: *Contemporary trends in insurance at the beginning of the fourth industrial revolution*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 3-19.

Credit Card Fraud Detection

In this section, we will demonstrate the possibilities of using machine learning in credit card fraud detection, as one of the highly significant methods for managing the risk of insuring financial losses due to credit card data theft. In 2025, Hafez, Hafez, Saleh, et al. published a systematic review of the studies included in the Scopus database that dealt with credit card fraud detection. Their review showed that this topic was covered in as many as 628 studies, but they based their analysis on 52 studies according to the inclusion and exclusion criteria.⁵⁹⁶ Credit card fraud remains a rising concern in the U.S. financial landscape, with recent data specifying that 63% of credit card holders have been victims of fraud. In 2023, over 62 million Americans reported unauthorised charges, resulting in losses exceeding \$6.2 billion annually. Furthermore, only 8% of these cases involved physically stolen or lost cards, with the majority arising from remote access to account credentials and sensitive personal data.⁵⁹⁷ Traditional fraud detection methods, reliant on predefined rule-based approaches, often suffer from inefficiencies, producing high false-positive and false-negative rates. To address these limitations, machine learning-based solutions have been developed to enhance fraud detection accuracy by learning complex transaction patterns and identifying anomalies in real time.⁵⁹⁸

The dataset utilised in this study was sourced from the Kaggle dataset website and comprises 284,807 transactions across 31 features.⁵⁹⁹ A key characteristic of this dataset is the application of Principal Component Analysis (PCA) to transform 28 of these features (V1-V28). The decision to employ PCA stems from the need to anonymise sensitive transactional data while preserving the statistical integrity of the dataset. PCA effectively reduces dimensionality by capturing the most significant variance in the data, eliminating multicollinearity, and mitigating overfitting risks. Furthermore, PCA enhances computational efficiency, allowing models to process transactional data at scale while focusing

⁵⁹⁶ Hafez, I. Y., Hafez, A. Y., Saleh, A., Abbas, A., Mostafa, A., & Abdelrahman, A. (2025). A systematic review of AI-enhanced techniques in credit card fraud detection. *Journal of Big Data*, 12, Article 6. <https://doi.org/10.1186/s40537-024-01048-8>

⁵⁹⁷ Cruz, B. (2025). 62 million Americans experienced credit card fraud last year. *Security.org*. Retrieved February 17, 2025, from <https://www.security.org/digital-safety/credit-card-fraud-report/>

⁵⁹⁸ Mohammed, M. A., Kothapalli, K. R. V., Mohammed, R., Pasam, P., Sachani, D. K., & Richardson, N. (2017). Machine learning-based real-time fraud detection in financial transactions. *Asian Accounting and Auditing Advancement*, 8, pp. 67-76.

⁵⁹⁹ Kaggle (n.d.). *Homepage*. <https://www.kaggle.com>

on the most informative patterns.⁶⁰⁰ The remaining three features in the dataset include Time, which represents the seconds elapsed between a given transaction and the first transaction in the dataset, Amount, which denotes the transaction value, and Class, which is the target variable where fraud is denoted by 1 and non-fraud by 0.

A fundamental challenge in fraud detection is the extreme imbalance in class distribution, with fraudulent transactions constituting only 0.17% of the dataset. Training machine learning models on such skewed data inherently biases predictions towards the majority class, leading to poor fraud detection capabilities. To counteract this, Synthetic Minority Over-Sampling Technique (SMOTE) and Random Under-Sampling (RUS) were employed. SMOTE addresses class imbalance by generating synthetic fraudulent transactions rather than duplicating existing ones. This is achieved by interpolating between minority class samples, thereby preserving feature relationships and increasing the diversity of fraudulent transaction representations within the dataset.⁶⁰¹ By contrast, RUS mitigates class imbalance by randomly removing instances from the majority class, reducing computational complexity but at the risk of discarding valuable information. A balanced dataset was ultimately achieved, consisting of 4,920 non-fraudulent transactions and 2,460 fraudulent transactions.⁶⁰²

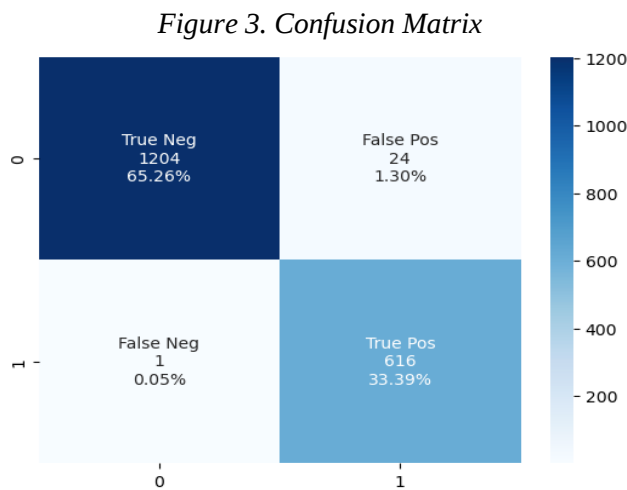
Exploratory data analysis revealed distinct behavioural differences between fraudulent and non-fraudulent transactions. On average, fraudulent transactions occur in shorter time intervals compared to legitimate ones, indicating a pattern of rapid, unauthorised purchases. Additionally, the mean transaction amount for fraudulent cases is significantly higher (\$122.2) than for non-fraudulent cases (\$88.3), reinforcing the notion that fraudsters typically execute high-value transactions before detection mechanisms can intervene. To ensure the selection of the most predictive features, an Analysis of Variance (ANOVA) test was conducted, ranking features based on their statistical relevance to the target variable. Features with an ANOVA score below 50 were discarded, allowing the model to focus on attributes that exhibit the strongest discriminatory power between fraudulent and non-fraudulent transactions.

⁶⁰⁰ Jolliffe, I. T. (2002). *Principal component analysis*, 2nd ed., Springer.

⁶⁰¹ Chawla, N. V., Bowyer, K. W., Hall, L. O., & Kegelmeyer, W. P. (2002). SMOTE: Synthetic minority over-sampling technique. *Journal of Artificial Intelligence Research*, 16, pp. 321-357.

⁶⁰² He, H., & Garcia, E. A. (2009). Learning from imbalanced data. *IEEE Transactions on Knowledge and Data Engineering*, 21(9), pp. 1263-1284.

The dataset was subsequently partitioned into training and testing sets, with a 75%-25% split. Given the synthetic nature of the minority class samples generated through SMOTE, model evaluation could not rely solely on accuracy, as this metric does not adequately reflect the model’s ability to detect rare fraudulent cases. Instead, performance was assessed using Cross-Validation Score and the Receiver Operating Characteristic – Area Under the Curve (ROC-AUC) Score. Cross-validation was employed to ensure the model’s generalizability across different data subsets by iteratively training and testing on multiple splits of the dataset. The model achieved a mean cross-validation accuracy of 98.37%, demonstrating its ability to maintain high predictive performance across different data partitions. The ROC-AUC score, which evaluates the model’s trade-off between true positive and false positive rates, was measured at 0.9951, indicating excellent fraud detection capability. The model’s false positive rate was recorded at 1.3%, meaning that 1.3% of legitimate transactions were incorrectly flagged as fraudulent. More critically, the false negative rate was 0.05%, ensuring that only a negligible percentage of fraudulent transactions went undetected.



Source: Author’s calculation

Table 1. ROC AUC score and cross-validation calculation

Mean cross-validation accuracy	0.9837
ROC AUC Score	0.9951

Source: Author’s calculation

While the model successfully distinguishes fraudulent from non-fraudulent transactions, further improvements can be made by expanding the feature space

to incorporate additional contextual variables. Governments and financial institutions should consider integrating transactional metadata such as geolocation data, timestamps, temporal gaps between successive transactions in different locations, client identification numbers, linked bank accounts, email addresses, and device information. The inclusion of transaction type classifications—such as cash withdrawals, e-commerce purchases, bill payments, and foreign transactions—would further refine fraud probability estimation. Beyond feature augmentation, the adoption of deep learning techniques, particularly Recurrent Neural Networks (RNNs) and Transformer-based architectures, could enhance fraud detection by capturing sequential dependencies in transactional behaviors. These advanced models excel in learning temporal patterns, enabling them to detect sophisticated fraud strategies that evolve over time. In addition to technological advancements, regulatory interventions are necessary to strengthen fraud prevention frameworks. Governments should enforce real-time transaction monitoring standards, mandate secure authentication mechanisms such as multi-factor authentication (MFA) and biometric verification, and establish data-sharing protocols among financial institutions to facilitate collaborative fraud detection efforts. The implementation of adaptive fraud detection algorithms that dynamically adjust risk thresholds based on transaction history and behavioural patterns would further enhance the robustness of fraud prevention systems. The model achieved a sophisticated level of predictive accuracy. Future research should focus on integrating richer transactional features, leveraging deep learning methodologies, and advocating for policy reforms to create a more secure and resilient financial ecosystem.

Car insurance claim classification

The ability to predict car insurance claims with high precision is an essential factor in optimising risk management strategies for insurance providers. Accurate claim prediction enables insurers to mitigate financial losses, adjust premium pricing models, and identify high-risk policyholders, thereby enhancing operational efficiency and customer satisfaction. Leveraging machine learning techniques for this task involves extensive data preprocessing, feature engineering, and model optimization to ensure robust predictive performance. This study implements three machine learning algorithms – Random Forest, Logistic Regression, and K-Nearest Neighbors (KNN), to construct a predictive framework using a dataset sourced from Kaggle, containing 10,000 observations and 32 features.

The dataset encapsulates a diverse set of policyholder attributes, including demographic characteristics such as AGE, GENDER, EDUCATION, and RACE,

financial metrics such as INCOME and CREDIT_SCORE, as well as driving behaviour indicators such as SPEEDING_VIOLATIONS, DUIS, and PAST_ACCIDENTS. The target variable, OUTCOME, represents whether a policyholder has filed an insurance claim, thus formulating a binary classification problem. Initial exploratory data analysis revealed that claimants aged 26–29 with 0–9 years of driving experience constitute a significant proportion of insurance clients. Furthermore, claim behaviour varies across income brackets, with upper-class individuals primarily insuring sedans. The dataset exhibited missing values in CREDIT_SCORE and ANNUAL_MILEAGE, which were imputed using median values to preserve data integrity. Categorical variables (AGE, DRIVING_EXPERIENCE, EDUCATION, INCOME, POSTAL_CODE) were transformed using one-hot encoding to facilitate their inclusion in machine learning models. Given the inherent class imbalance in the dataset, where claim occurrences are underrepresented, SMOTE was employed to generate synthetic instances of the minority class, ensuring equitable representation in model training.

Random Forest is an ensemble learning method that constructs multiple decision trees during training and outputs the mode of the classes for classification tasks. It is particularly advantageous for handling complex, non-linear relationships in large datasets and is robust to overfitting. However, its main drawback lies in its higher computational cost, and the model's interpretability can be limited due to the complexity of combining numerous decision trees.⁶⁰³ The K-Nearest Neighbors (KNN) classifier works by assigning a new data point to the majority class of its k nearest neighbors based on distance metrics. This algorithm is advantageous for non-linear data distributions and does not require explicit training, making it a simple and intuitive model. However, KNN can become computationally expensive during the prediction phase, especially for large datasets, as it requires distance calculations for each new sample. Moreover, KNN's performance is highly dependent on the choice of the number of neighbors and the distance metric used.⁶⁰⁴ Logistic Regression is a linear model that estimates the probability of a binary outcome by applying a logistic function to a set of features. This model is widely appreciated for its simplicity, interpretability, and the ability to provide statistical insights into how individual features contribute to the prediction. However, it assumes a linear relationship

⁶⁰³ Breiman, L. (2001). Random forests. *Machine Learning*, 45, pp. 5-32.

⁶⁰⁴ Kataria, A., & Singh, M. D. (2013). A review of data classification using K-nearest neighbour algorithm. *International Journal of Emerging Technology and Advanced Engineering*, 3(6), p. 354.

between features and the outcome, which may limit its performance in more complex, non-linear scenarios.⁶⁰⁵

Table 2. Classification report of three different models

Model	Precision	Recall	F1-score	Support
Random Forest				
Class 0	0.8832	0.8724	0.8778	1317
Class 1	0.8838	0.8937	0.8887	1430
Accuracy			0.8835	2747
Macro Avg	0.8835	0.8831	0.8833	2747
Weighted Avg	0.8835	0.8835	0.8835	2747
K-Nearest Neighbors				
Class 0	0.8985	0.8064	0.8499	1317
Class 1	0.8371	0.9161	0.8748	1430
Accuracy			0.8635	2747
Macro Avg	0.8678	0.8612	0.8624	2747
Weighted Avg	0.8665	0.8635	0.8629	2747
Logistic Regression				
Class 0	0.8429	0.8231	0.8329	1317
Class 1	0.8405	0.8587	0.8495	1430
Accuracy			0.8416	2747
Macro Avg	0.8417	0.8409	0.8412	2747
Weighted Avg	0.8417	0.8416	0.8416	2747

Source: Author's calculation

To evaluate the effectiveness of the algorithms, several key metrics were considered. Precision measures the proportion of true positives among all instances classified as positive, making it essential for minimising false positives, important in scenarios such as insurance claims, where non-claimants should not be mistakenly classified as claimants. Recall, on the other hand, focuses on the proportion of actual positives that are correctly identified, ensuring that genuine claim cases are not overlooked. The F1-score, the harmonic mean of precision and recall, is particularly valuable when balancing both metrics is crucial, as it

⁶⁰⁵ Zou, X., Hu, Y., Tian, Z., & Shen, K. (2019). Logistic regression model optimization and case analysis. In: *Proceedings of the IEEE 7th International Conference on Computer Science and Network Technology (ICCSNT)*, IEEE.

provides a unified measure of classification effectiveness.⁶⁰⁶ While accuracy is often a commonly referenced metric, it can be misleading in imbalanced datasets. In these cases, the Area Under the ROC Curve (AUC-ROC) is an additional metric that was used to assess model performance, with Random Forest attaining the highest score of 0.89, confirming its superior classification power.⁶⁰⁷

From the results presented in Table 2, the Random Forest model exhibits the best overall performance. The precision for non-claimants (class 0) is 0.8832, and for claimants (class 1), it is 0.8838, with recall values of 0.8724 and 0.8937, respectively. The model's F1-scores of 0.8778 and 0.8887 further highlight its ability to balance both metrics effectively, confirming its status as the top-performing model. The KNN classifier demonstrated a strong recall performance of 91.61% for claimants (class 1), showing its ability to identify claim-prone policyholders. However, the precision for class 1 is lower at 83.71%, which indicates that the model is prone to classifying non-claimants as claimants, resulting in false positives. This is reflected in its overall F1-score of 0.8624, which indicates a solid balance between recall and precision, but with a tendency to misclassify non-claimants as claimants. The accuracy of 86.35% underscores its strength in identifying claimants, but it comes at the expense of precision for non-claimants. Logistic Regression, serving as the baseline model, showed slightly lower performance than Random Forest, with an accuracy of 84.16%. The precision for non-claimants is 0.8429, and for claimants, it is 0.8405, while recall is 0.8231 and 0.8587, respectively. Although its simpler structure offers better interpretability and insight into how individual features contribute to the prediction, it was less effective in accurately classifying both claimants and non-claimants compared to the more complex models. In summary, Random Forest offers the best overall performance, particularly in balancing precision and recall. Interestingly, when Hanafy, M., & Ming, R. (2022) applied ML methods: logistic regression, XGBoost, random forest, decision trees, naïve Bayes, and K-NN to predict claim occurrence on the dataset given by Porto Seguro, a large Brazilian automotive company, they also concluded that Random Forest proved better compared to the other methods.⁶⁰⁸ KNN excels in recall but suffers from a trade-

⁶⁰⁶ Saito, T., & Rehmsmeier, M. (2015). The precision-recall plot is more informative than the ROC plot when evaluating binary classifiers on imbalanced datasets. *PLOS ONE*, 10(3), e0118432. <https://doi.org/10.1371/journal.pone.0118432>

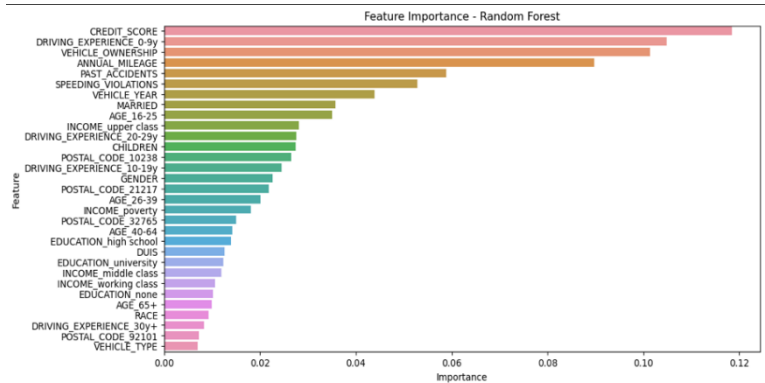
⁶⁰⁷ Fernández-Delgado, M., Cernadas, E., Barro, S., & Amorim, D. (2014). Do we need hundreds of classifiers to solve real world classification problems? *Journal of Machine Learning Research*, 15(1), pp. 3133-3181.

⁶⁰⁸ Hanafy, M., & Ming, R. (2022). Classification of the insured using integrated machine learning algorithms: A comparative study. *Applied Artificial Intelligence*, 36(1), pp. 1-18. <https://doi.org/10.1080/08839514.2021.2020489>

off in precision, particularly for non-claimants, while Logistic Regression, though interpretable, performs slightly worse than the more complex models in terms of both accuracy and classification effectiveness.

Regarding Figure 4, feature importance analysis demonstrated that CREDIT_SCORE, DRIVING_EXPERIENCE_0-9y, VEHICLE_OWNERSHIP, and ANNUAL_MILEAGE had the highest predictive power.

Figure 4. Feature Importance in Random Forest model



Source: Author's calculation

While the current models yield substantial predictive accuracy, incorporating external data sources and advanced modelling techniques could further enhance claim prediction reliability. Telematics data integration through real-time vehicle sensors, including braking patterns, acceleration behaviour, and mileage tracking, would enable a more dynamic assessment of risk profiles. The use of GPS tracking data would allow insurers to analyse driving patterns, road conditions, and accident-prone zones, correlating claim likelihood with environmental risk factors such as urban congestion, hazardous weather conditions, and high-speed corridors. Additionally, incorporating historical claim patterns, policy renewal history, and social determinants such as employment sector and travel frequency could refine risk stratification.⁶⁰⁹ Deep learning architectures, including recurrent neural networks (RNNs) and transformer-based models, offer another avenue for improvement by capturing sequential dependencies in driving behaviour, financial transactions, and claim history. Autoencoders could enhance anomaly detection, aiding in the identification of fraudulent claims. Furthermore, regulatory and behavioural economics insights should be incorporated into predictive models to account for the impact of policyholder psychology, incentive

⁶⁰⁹ Baecke, P., & Bocca, L. (2017). The value of vehicle telematics data in insurance risk selection processes. *Decision Support Systems*, 98, pp. 69-79.

structures, and compliance frameworks. Reinforcement learning techniques may be applied to optimise dynamic pricing models based on real-time behavioural adjustments.⁶¹⁰ The empirical findings of this study underscore the potential of machine learning in optimising insurance risk assessment. By integrating multimodal data sources and leveraging advanced algorithmic techniques, insurers can achieve a more granular and dynamic understanding of claim probabilities, ultimately leading to more efficient claims processing, reduced fraudulent activities, and personalised policy offerings.

The key role of actuaries is to ensure that advanced modelling techniques are appropriately tailored to meet the criteria necessary for their sound and controlled use, to understand and manage the outcomes of these models, while acting in the public interest to ensure that such techniques are applied ethically and responsibly.

The source codes and implementation details for the machine learning models used in this study can be accessed via the following GitHub repositories:

<https://github.com/bradickristina/frauddetection.git>

<https://github.com/bradickristina/CarInsuranceClaims.git>

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⁶¹⁰ Boylan, J., Meyer, D., & Chen, W. S. (2024). A systematic review of the use of in-vehicle telematics in monitoring driving behaviours. *Accident Analysis & Prevention*, 199, 107519.

Chapter 21.

DETECTING OUTLIERS IN CLAIM DATA USING MACHINE LEARNING

In general, outliers are items that are significantly different from the majority of other items they may be compared to. In this chapter, we use the term anomaly synonymously, though also often to indicate a single unusual property of an item: the individual oddities that make an item an outlier.

Outlier detection refers to the process of finding items that are unusual⁶¹¹. For tabular data, this usually means identifying unusual rows in a table; for image data, unusual images; for text data, unusual documents, and similarly for other types of data. The specific definitions of “normal” and “unusual” can vary, but at a fundamental level, outlier detection operates on the assumption that the majority of items within a dataset can be considered normal, while those that differ significantly from the majority may be considered unusual, or outliers. For instance, when working with a database of claims, we assume that the majority of claims represent normal behaviour, and our goal would be to locate the claim that stands out as distinct from these.

In statistical theory, outliers can arise due to measurement errors, an error in data transmission, elements outside the population being incorrectly included in the population, a flaw in an assumed theory, or genuine variability. Identifying outliers is crucial, as they can skew statistical analysis and lead to misleading conclusions. Applications of outlier detection include fraud detection, bot detection on social media⁶¹², network security, financial auditing, regulatory oversight of financial markets, medical diagnosis, astronomy, data quality and the development of autonomous vehicles.

It’s important to note that not all outliers are necessarily problematic, and in fact, many are not even interesting. Outlier detection can be seen as being not merely interested in removing noise but also in finding interesting database objects deviating in their behaviour considerably from the majority and, as such, providing new insights. Inconsistency can mean that the data object is contaminated from a different distribution than the model considered to describe

⁶¹¹ Kennedy, B. (2024). *Outlier detection in Python*. Shelter Island: Manning.

⁶¹² Rahman, M. S., Halder, S., Uddin, M. A. et al. (2021). An efficient hybrid system for anomaly detection in social networks. *Cybersecurity*, 4(1), 10.

the data. But inconsistency could also mean that the pre-supposed model is not describing the data as well as was assumed when selecting the model. Both conclusions can bear rather significant repercussions on the interpretation of the given observations.

There are several ways to find fraudulent records in tabular data. If we have economic or financial data, we can use a group of methods based on Benford's law.⁶¹³ However, its weakness is sensitivity to sample size. In this chapter, we will show how the same task can be solved using unsupervised learning techniques for detecting outliers from insurance data. By applying both techniques, the pool of suspicious records would be smaller, which could lead to savings in audit work.

1. OUTLIER DETECTION'S PLACE IN MACHINE LEARNING

Outlier detection is a machine learning technique, which means it learns from data rather than using rules created by people. There are various outlier detection techniques in machine learning, which are categorized as supervised or unsupervised methods.

Supervised learning uses a labelled training dataset to understand the relationships between input and output data⁶¹⁴ (identify outliers in our case). Data scientists manually create training datasets containing input data along with the corresponding labels. Supervised learning trains the model to apply the correct output to new input data in real-world data. In that setting, we are given a set of data, possibly a spreadsheet of records, a collection of text documents, a time sequence of instrument readings, or audio files. What makes a problem supervised is the fact that the data includes what are called labels. As an example, assume that we have a spreadsheet of records from past insurance claims. The labels will in some way describe each record. For example, let's consider a scenario in which we have tabular data with the following fields: date, claim, agent, description and agency, and the labels may refer to the type of record - „fraudulent“ or „non-fraudulent“. Given this, the goal would be to utilize supervised machine learning in order to create a predictor. This predictor, more

⁶¹³ Azdejković, D. (2024). Poboljšanje efikasnosti nekih testova forenzičke analitike. In: *2024 Perspektive razvoja forenzičko-računovodstvenih kapaciteta: izazovi za javni i korporativni sektor*. Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 335-345.

⁶¹⁴ Van Wyk, F., Wang, Y., Khojandi, A., & Masoud, N. (2019). Real-time sensor anomaly detection and identification in automated vehicles. *IEEE Transactions on Intelligent Transportation Systems*, 21(3), pp. 1264-1276.

specifically, is referred to as a *classifier* if the labels represent categories (also known as classes); the classifier will learn to predict the class labels from the record (in this case, predicting the type of claim in a record). And the predictor is referred to as a *regressor* if the labels are numeric values (for example, if we had labels representing the pictures, such as the number of distinct cars in the picture); the regressor will learn to predict these numeric values from the images. The labels here are said to supervise the learning process.

Supervised learning in insurance often revolves around using labelled data to make predictions, assess risk, or enhance customer experience. Here are some examples from the insurance industry:

- *Claim fraud detection* - historical data from past insurance claims, labelled as "fraudulent" or "non-fraudulent," is used to train a machine learning model. By identifying patterns and features associated with fraudulent claims (e.g., unusual claim amounts, repeated claims from the same individual, or inconsistencies in provided information), the model can predict the likelihood of fraud in new claims⁶¹⁵.
- *Premium pricing* - models trained on customer data (age, health, driving records, etc.) labelled with premium amounts can help insurers determine the appropriate premium rates for new customers⁶¹⁶.
- *Risk assessment* - using labelled data about accidents or policy lapses, supervised learning models predict the likelihood of these events for potential clients⁶¹⁷.
- *Customer segmentation* - learning from labelled data about customer behaviour and preferences, insurers group clients into categories for targeted marketing⁶¹⁸.

However, often when we are working with data, there are no labels, just the data itself. So, in *unsupervised learning*, we do not label the data with which we want to train the model. The model learns through training itself from the data. Here are some examples from the insurance field:

⁶¹⁵ Debener, J., Heinke, V., & Kriebel, J. (2023). Detecting insurance fraud using supervised and unsupervised machine learning. *Journal of Risk and Insurance*, 90(3), pp. 743-768.

⁶¹⁶ Gu, S., Kelly, B., & Xiu, D. (2020). Empirical asset pricing via machine learning. *The Review of Financial Studies*, 33(5), pp. 2223-2273.

⁶¹⁷ Paltrinieri, N., Comfort, L., & Reniers, G. (2019). Learning about risk: Machine learning for risk assessment. *Safety science*, 118, pp. 475-486.

⁶¹⁸ Ozan, Ş. (2018). A case study on customer segmentation by using machine learning methods. In: *2018 International Conference on Artificial Intelligence and Data Processing (IDAP)*, IEEE, pp. 1-6.

- *Customer segmentation*: Using customer data without predefined labels, an unsupervised learning model can group customers based on shared characteristics (e.g., purchasing behaviour, claim history, demographics). These segments can help insurers design targeted marketing strategies, offer personalized policies, or identify underserved customer groups⁶¹⁹.
- *Risk profiling*: Clustering policyholders based on risk levels, which can assist in better pricing and policy design⁶²⁰.
- *Fraud detection*: Identifying unusual patterns or anomalies in claim data that could indicate potential fraud⁶²¹.
- *Policy optimization*: Grouping similar types of insurance policies to identify trends and optimize product offerings⁶²².

When clustering data, we find sets of items that appear to be similar to each other. A clustering algorithm for a given spreadsheet of records would examine the records and divide them into a small set of clusters, based on perhaps the agent's name, the amount of claim and other properties of the record. This would be done such that each cluster is internally consistent (the records in each cluster are similar to each other) and the different clusters are unlike each other.

Outlier detection, on the other hand, identifies the most unusual items in a dataset. This is based on something quite powerful: learning the fundamental patterns of a given set of data, what constitutes normal for this data, and what items diverge most strongly from these patterns.

Prediction and outlier detection do different things—both are useful, but quite different. When labels are available, it can often be more useful to create a predictive model than to perform unsupervised analysis such as clustering or outlier detection. We can train a classifier to learn what types of records represent fraudulent records. Then, given any new record, the classifier can predict

⁶¹⁹ Shen, B. (2021). E-commerce customer segmentation via unsupervised machine learning. *The 2nd international conference on computing and data science*, pp. 1-7.

⁶²⁰ Bao, W., Lianju, N., & Yue, K. (2019). Integration of unsupervised and supervised machine learning algorithms for credit risk assessment. *Expert Systems with Applications*, 128, pp. 301-315.

⁶²¹ Rai, A. K., & Dwivedi, R. K. (2020). Fraud detection in credit card data using unsupervised machine learning based scheme. In: *2020 international conference on electronics and sustainable communication systems (ICESC)*, IEEE, pp. 421-426.

⁶²² Shen, J., Zhao, H., Zhang, W., & Yu, Y. (2020). Model-based policy optimization with unsupervised model adaptation. *Advances in Neural Information Processing Systems*, 33, pp. 2823-2834.

what type of record it is. However, what a classifier cannot do well is recognise when it is given an unusual record, perhaps a record not belonging to one of the classes it was trained to predict. These are problems outlier detectors can solve: recognising which of the data we may be faced with, if any, is unusual.

Definitions of outliers

We will try to more precisely define what outliers are, although it is possible to a degree since outliers are a fuzzy concept. This has some advantages, as it allows us to approach outlier detection from many different fields, but it also carries a lot of vagueness. The fact is that the context makes a great deal of difference. What might be noise in one context may be a signal in another. Here are a few definitions that we often see in academic literature, each useful, but each a little vague.

Grubbs⁶²³ stated “*an outlying observation, or outlier, is one that appears to deviate markedly from the other members of the sample in which it occurs.*”

Barnett and Lewis⁶²⁴ used the following definition: “*An observation (or subset of observations) which appears to be inconsistent with the remainder of that set of data.*” This broadens the concept of outliers as it adds the idea of collective outliers as well as single items (e.g., single credit card purchases) being unusual; a set of several (e.g., a series of credit card purchases over a few hours) may be an outlier, even if each item in a set is typical.

One of the most cited definitions of outliers is from Hawkins⁶²⁵: “*An outlier is an observation which deviates so much from the other observations as to arouse suspicions that it was generated by a different mechanism.*” This definition is based on an important idea: that there is some process, or set of processes, generating the data and that they operate within certain bounds. Other data, generated by other processes, can become included in a dataset and would then be considered anomalous. For example, we could consider the payment processes in one company that include the purchase of office supplies and the payment of utility services. Each process will generate a set of costs, which will be included in the cost table. However, utility payment processes will be far less frequent and larger, so they could be considered outliers, even though they are completely

⁶²³ Grubbs, F. (1969). Procedures for Detecting Outlying Observations in Samples. *Technometrics*, 11(1), pp. 1-21.

⁶²⁴ Barnett, V., & Lewis T. (1994). *Outliers in Statistical Data*. New York: John Wiley & Sons.

⁶²⁵ Hawkins, D. (1980). *Identification of Outliers*. Chapman & Hall.

legitimate. On the other hand, it can result in an employee entering incorrect data, which may lead to possible fraud. As these are different processes, they create records that are fundamentally different.

Despite the common need to identify unusual data points and despite these intuitive definitions, no universally accepted definition of specifically what qualifies as “unusual” exists. This means it’s very difficult to say what items should be flagged as outliers. With no labels, there is no systematic way to evaluate any outliers flagged, and without a concrete definition, there is no definite way to create labels. Outlier detection is, then, highly subjective.

Take Figure 1, for example. It shows eight wine glasses. We might ask: Which glasses are unusual? Just by looking at the picture, we can begin to see many ways in which we might consider some of the glasses unusual. They differ in size, shape, the colour of the wine in them, and so on. Different people might come to different conclusions based on the picture. Some might argue that all the glasses are similar, so none of them is unusual. Others might say that the one in the second row on the far right is different from the others, so it could be considered unusual, and so on.

Figure 1. Which glass is an outlier?



Source: <https://macyswineshop.com>

Trends in identifying outliers

Outlier detection has gone through three major stages, starting with traditional, simple statistical methods (for example, based on z-score), going back many decades⁶²⁶. These were straightforward and could be computed by hand for small datasets, but were limited to finding unusually small or large values in single sequences of numbers and don’t extend well to tables of data.

⁶²⁶ Aguinis, H., Gottfredson, R. K., & Joo, H. (2013). Best-practice recommendations for defining, identifying, and handling outliers. *Organizational research methods*, 16(2), pp. 270-301.

These were followed by machine learning-based methods, largely from the last 30 or so years, developed as computer hardware improved, digitised data became common, and machine learning techniques improved. We will refer to these here as traditional machine learning to distinguish them from the third major stage, which has advanced significantly in the last several years: the development of deep learning-based methods—methods based on deep neural networks. This has been crucial in some areas; outlier detection with vision, text, or audio would not be possible without deep learning. All three forms of outlier detection now play a valuable role in analysing data and searching for anomalies.

Where we have the most opportunity to improve traditional machine learning-based outlier detection with tabular data is by improving the collection and sharing of data. As outlier detection is based on data, it benefits from the explosion in data we are now producing and collecting. We now have a wealth of data to compare against, which allows us to develop a better sense of what is normal and what is not, which allows outlier detectors to be much more sensitive and accurate. A great deal of this data, though, is proprietary, owned by single organisations.

2. THE OUTLIER DETECTION PROCESS

The outlier detection process typically involves several key steps:

1. *Understanding the data:* Begin by exploring the dataset to understand its structure, distribution, and context. This includes identifying the type of data (numerical, categorical, etc.) and any domain-specific considerations.
2. *Preprocessing:* Clean the data by handling missing values, removing duplicates, and normalising or scaling features. This ensures that the data is ready for analysis.
3. *Choosing a detection method:* Select an appropriate method based on the dataset and the type of outliers you expect. Common methods include:
 - Statistical techniques like z-scores or Interquartile Range (IQR).
 - Machine learning methods like Isolation Forests, Autoencoders, or clustering algorithms.
4. *Applying the method:* Implement the chosen method to identify potential outliers. This may involve setting thresholds or parameters to define what constitutes an outlier.
5. *Validating results:* Review the identified outliers to ensure they are truly anomalous and not just unusual but valid data points. Domain knowledge is crucial here.

6. *Handling outliers*: Decide how to handle the outliers—whether to remove them, transform them, or analyse them separately. The approach depends on the specific goals of the analysis.
7. *Iterative refinement*: Repeat the process as needed, especially if new data is added or the context changes.

This process can be tailored to specific applications, such as fraud detection, quality control, or predictive modeling.

3. SIMPLE OUTLIER DETECTION

Outlier detection has a long history in statistics, and many well-established, simple methods exist, but they are usually univariate and often assume specific data distributions, typically that the data have a Gaussian distribution or approximately a Gaussian distribution. They are designed specifically to find extreme values, the unusually small and large values in sequences of numeric values. These are the easiest outlier tests to understand and provide a good background for the machine learning based approaches we will focus on later. Statistical methods have some significant limitations. They work on single columns of numeric data and often don't extend well to tables.

One-dimensional numeric outliers

Statistical methods to identify outliers in a sequence of numbers include tests based on z-scores, interquartile range (IQR), and median absolute deviation (MAD). All tests are based on a simple approach: we calculate the score for value in data and flag values over or below a predefined threshold.

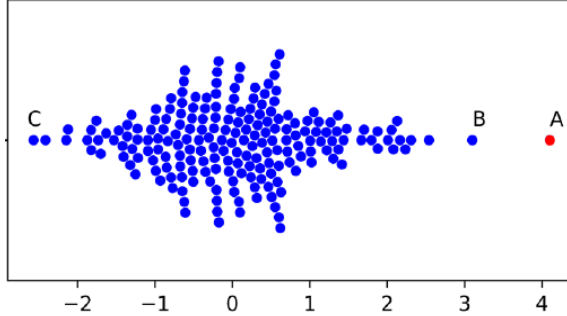
For a given set of numbers, we calculate the z-score for value x_i as

$$z_i = \frac{x_i - \bar{x}}{\bar{s}}$$

Any value with a z-score below -3 and above 3 we flag as an outlier. The threshold is based on the fact that if some data has a Gaussian distribution, then less than 0.3% of the data is above 3 or below -3. The main disadvantage of the z-score method is its sensitivity to outliers. The presence of an outlier in the data significantly affects the calculation of the arithmetic mean and standard deviation, and thus the ability to find other outliers. In particular, the z-score method allows masking and swamping effects. This is shown in Figure 2: if A is not present in the data, then B is not an outlier (masking), but if A is present in the data, then C is an outlier.

A lesson from the z-score method is that we should be very careful when using mean and standard deviation in detecting outliers. Most of the methods in common usage are much more robust to outliers. If we calculate the mean and standard deviation after removing some percentage of the top and bottom values in the data, we can get a more robust method.

Figure 2. Swamping and masking



Source: Kennedy (2024), *op. cit.*, p. 28.

Interquartile range test, as the name suggests, uses the interquartile range $IQR = Q_3 - Q_1$ to define a bottom threshold $Q_1 - \theta \cdot IQR$ and upper threshold $Q_3 + \theta \cdot IQR$, where θ is a parameter. Although John Tukey⁶²⁷ who developed the test had a long tradition of using $\theta = 1.5$, today's standard is $\theta = 2.2$. The main advantage of the interquartile range test is that it is much more robust to outliers than z-scores.

Finally, if we want a much more robust method, we have to use median absolute deviation (MAD). Let $x = (x_1, x_2, \dots, x_n)$ be the set of observed values, then MAD is defined by:

$$MAD(x) = Med\{|x - Med(x)|\}.$$

where $Med(x)$ is the median. To determine if a value is an outlier using MAD, we calculate the so-called normalised MAD (MADN):

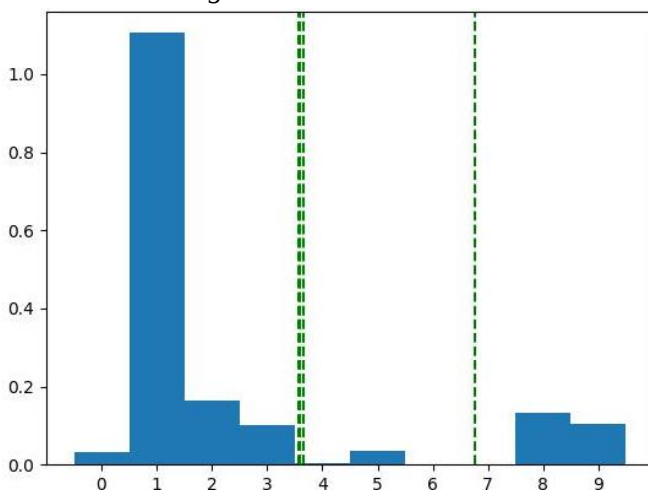
$$MADN(x_i) = \frac{0.6745(x_i - Med(x))}{MAD(x)}$$

The constant 0.6745 in this formula is used to make it equivalent to the z-score formula when the data are normally distributed. With MADN, usually 3.0 or 3.5 is used for the threshold.

⁶²⁷ Tukey, J. W. (1977). *Exploratory Data Analysis*. Massachusetts: Addison-Wesley.

Previous methods are intended to identify extreme values and will miss so-called *internal outliers*. Internal outliers exist in multimodal distributions or distributions with gaps. Histograms are possibly the easiest method to identify internal outliers, especially if we use, for example, the pandas library from Python for constructing a histogram object. The idea of histograms is to divide the space into sets of equal-width bins and calculate the count of each bin. This provides clear insight into the distribution of the same and allows us to flag bins with unusually low counts as outliers. Drawback in using histograms is sensitivity to the number of bins, so we must be very careful in their construction. In Figure 3, we can see the histogram of the hue-mean feature from the segment dataset on the open machine learning site⁶²⁸. Segment data is divided into 10 histogram bins. The height of each bar indicates the number of records in the bin. Since our histogram is an object from the pandas library, it is not hard to flag bins which have quite low counts. In our case, we flag bins 5 and 8 with two dashed vertical lines. Points in those bins are internal outliers. Bin 6 has no records, and so, no outliers there.

Figure 3. Internal outlier



Source: Kennedy (2024), *op. cit.*, p. 35.

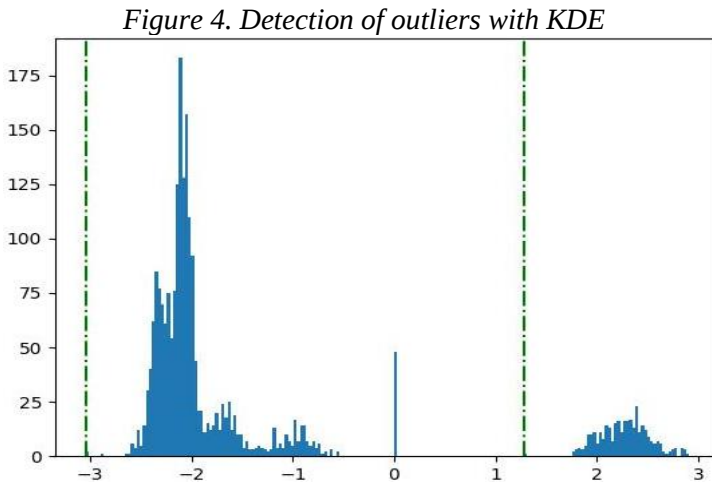
Kernel density estimation (KDE) works similarly to histograms. KDE estimates the density of data points across feature space as a continuous function. Points that lie in areas of low density (i.e., the tails of the distribution) are considered outliers. For a given set of data points $x_1, x_2, \dots, x_n$, KDE estimates the density at a point x as:

⁶²⁸ <https://www.openml.org/>

$$\hat{f} = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - x_i}{h}\right)$$

where K is a kernel function, and h is a smoothing parameter. In other words, an algorithm creates a small kernel, which is shaped as a triangle, rectangle, or Gaussian, where each datapoint is located. This is more robust than histograms, since it is based on many small kernels. Also, the method avoids the need to set the number of bins, but it is sensitive to the width of the kernel.

Using Python library for machine learning, scikit-learn for machine learning, and linear as kernel shape, we can create a KernelDensity object for the dataset. Once we have an estimation of the KDE function, the next challenge is to determine which values are unusually low. Figure 4 shows the points identified (flagged with vertical lines) as outliers in the dataset segment using this method.

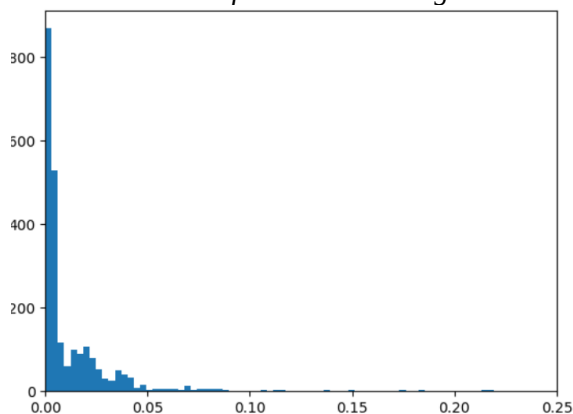


Source: Kennedy (2024), *op. cit.*, p. 38.

Outliers are typically points that are far from other points in the dataset. Since the K-Nearest Neighbors (KNN) method measures the distance from each point to other points, it can be used to detect outliers by examining how far a data point is from its k nearest neighbors. Given that the array of distances can be converted into a single number, which will represent the outliers of the point. Usually, converting is done by the mean or the maximum distance. A similar approach to KNN is to cluster the data and flag any points far from the nearest cluster centre. To implement this, we can use the data structure BallTree provided by the scikit-learn package from Python, which can calculate and store the distances between each pair of points in a dataset. The set of scores is not immediately interpretable,

and it is not clear what the cutoff is, so we will obviously focus on just the tail. Figure 5 shows the distribution of max scores using KNN with $k=20$ for the feature hue-mean from the dataset segment.

Figure 5. Distribution of max scores using KNN with $k=20$



Source: Author's calculations

One-dimensional categorical outliers

When discussing one-dimensional categorical outliers, we are talking about identifying unusual or rare categories within a single categorical variable. Unlike numerical outliers, which are identified based on their value's distance from the mean or distribution, categorical outliers are identified based on their infrequency or the lack of representation in the dataset.

If a particular category appears very infrequently compared to the other categories, it could be considered an outlier. Similarly, a category that occurs with such overwhelming frequency that it dominates all others could also be flagged as an outlier, although this is less common.

We could identify categorical outliers flagging the k rarest values or flagging any value occurring less than some predefined number of times, but that strategy has a weakness since we don't know how many categories we will have, and similarly, we do not know in advance how many instances of each distinct value to expect. We could also flag any value representing less than 1% of rows, but this may overreport, as it could be due to too many outliers.

A better approach is to evaluate the cumulative counts. If we sort unique values from least to most frequent and then calculate the cumulative sum, then we can

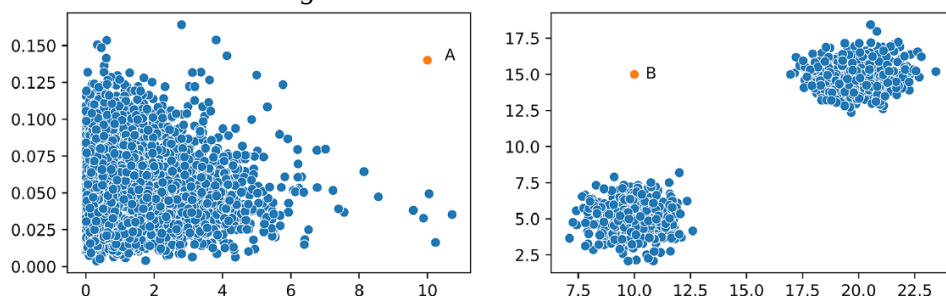
flag values under some threshold, such as 0.5%. This gives us a robust method which works very well in most cases. Another effective method is to apply some statistical methods to the set of counts to flag any unusually small counts.

Multidimensional outliers

In data science, we typically work with data tables and wish to flag unusual rows. Unlike in one-dimensional data, where an outlier is just a value that is too high or too low, multi-dimensional outliers are more complex and can be normal in individual dimensions but still abnormal when considered across all dimensions together. There are only two reasons to flag a row: (1) The row contains one or more unusual values; (2) The row contains one or more unusual combinations of values.

In Figure 6, we can see scatter plots with flagged outliers. Point A is an example of an outlier in one dimension (left plot), while point B is an example of a rare combination of values (right plot).

Figure 6. Rare combination outlier



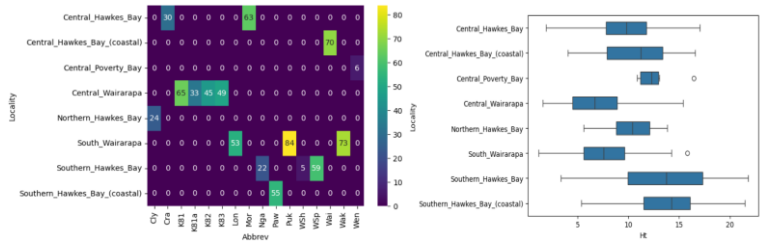
Source: Kennedy (2024), *op. cit.*, p. 45.

Working with tabular data, we may flag rows that have several values or several combinations of values.

A common method for the detection of outliers in table data is visualisation. The general strategy is to look at each feature, use some visualisation method and then also look at each pair of features. Investigating three or more features in a single plot is also possible, but very difficult. For two categorical features, a heatmap is a good choice, for two numeric features, a scatter plot is nice, while for one categorical and one numeric, a box plot could be a very good choice. Figure 7 shows examples of a heatmap and box plot based on two pairs of features from the eucalyptus dataset on the open machine learning site.

In practice, visualisations are used more to understand the data than to flag points as outliers, since, for example, a box plot could be a misleading method if the data is not unimodal.

Figure 7. Examples of visualisation in two dimensions

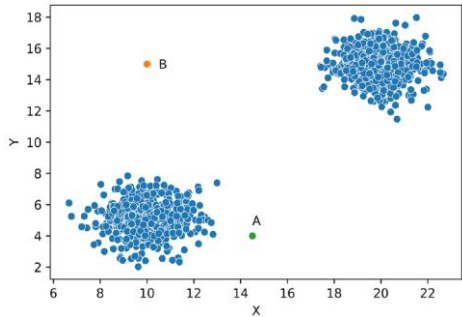


Source: Author's calculations

„Noise“ is a term which we use very often in machine learning. In the context of outlier detection, we use it to refer to points for which it is not clear whether it is are outliers or inliers. Most outlier detectors require setting a threshold or other parameters that will control how many records will be flagged as outliers. This is the way to control how much noise we allow in detecting outliers.

In outlier detection, working with data of at least two dimensions, we must establish the fundamental difference between what we call local and global outliers. The idea is easiest to show on a picture with numeric data.

Figure 8. Local and global outliers



Source: Kennedy (2024), op. cit., p. 51.

In Figure 8, point A is a local outlier since it is likely generated by the same process as points in the nearby cluster. On the other hand, point B is a global outlier, since it is distinct from almost all the data.

4. MACHINE LEARNING BASED OUTLIER DETECTION

While statistical techniques are useful for identifying outliers, they may not always be sufficient due to the following reasons: complex patterns, context dependence, multidimensional data, robustness to noise and dynamic datasets. Machine learning methods have significantly advanced the detection of outliers, offering more robust and adaptive solutions compared to traditional statistical techniques.

Isolation Forest (IF)

The Algorithm Isolation Forest was developed by Fei Tony Liu in 2008⁶²⁹. This algorithm works by isolating observations using random feature selection and split values, creating decision trees. Outliers, being fewer and more distinct, tend to have shorter path lengths in these trees compared to regular data points.

The algorithm is efficient (linear time complexity $O(n \log \log n)$), scalable for high-dimensional datasets, and requires less memory than other methods⁶³⁰.

The core idea of Isolation Forest is that anomalies are few and different, and thus, they are easier to isolate in a dataset. If we randomly partition the data, anomalies are likely to be isolated quickly because they differ significantly from normal points. The algorithm of IF has three main parts: Random partitioning of data, path length calculation and anomaly score computation.

In Random partitioning of data, the algorithm builds an ensemble of isolation trees, which are similar to decision trees. Each tree is built by randomly selecting a feature and then randomly selecting a split value between the minimum and maximum value of that feature. This process continues recursively to create branches until: The instance is isolated (i.e., placed alone in a leaf node), or a predefined maximum depth is reached, or the node has only one data point.

The path length is the number of edges (splits) required to isolate a given point. Anomalies tend to have shorter average path lengths in the tree ensemble because they are isolated quickly. Normal points require more splits (i.e., longer paths) to isolate because they are grouped with other similar points.

⁶²⁹ Liu, F. T., Ting, K. M., & Zhou, Z.-H. (2008). Isolation Forest. In: *2008 Eighth IEEE International Conference on Data Mining*, Pisa, pp. 413-422.

⁶³⁰ Liu, F. T., Ting, K. M., & Zhou, Z.-H. (2012). Isolation-Based Anomaly Detection. *ACM Transactions on Knowledge Discovery from Data*, 6(1), pp. 1-39.

For a point x , its anomaly score $s(x, n)$ is based on the average path length over all trees:

$$s(x, n) = 2 \frac{E(h(x))}{c(n)}$$

where $E(h(x))$ is the average path length of point x across the forest, $c(n)$ is the average path length of unsuccessful searches in a binary search tree, approximated as: $c(n) = 2H(n-1) - \frac{2(n-1)}{n}$ with $H(i)$ being the harmonic number: $H(i) \approx \ln \ln(i) + 0.5772$ (Euler-Mascheroni constant).

Finally, we interpret the score in the following way:

- ≈ 1 : High likelihood of anomaly
- < 0.5 : Normal
- ≈ 0.5 : Uncertain

The algorithm is implemented in Python using `sklearn.ensemble`.

Local Outlier Factor (LOF)

Local outlier factor is the best-known density-based algorithm used for anomaly detection in datasets, particularly in unsupervised learning contexts, proposed by Markus M. Breunig, Hans-Peter Kriegel, Raymond T. Ng and Jörg Sander in 2000⁶³¹. The intuition behind this algorithm is that the density around an outlier object is significantly different from the density around its neighbors. It assesses the “local” density deviation of a given data point with respect to its neighbors to determine if it behaves like an outlier.

Here are the steps in the LOF algorithm:

1. For each data point, LOF calculates its local neighborhood using k -nearest neighbors (k -NN).
2. Find local reachability density (LRD) using the following equation:

$$LRD_k(X) = \frac{N_k(X)}{\sum_{O \in N_k(X)} rd_k(X, O)},$$

⁶³¹ Breunig, M. M., Kriegel, H.-P., Ng, R. T., & Sander, J. (2000). LOF: Identifying Density-based Local Outliers (PDF). In: *Proceedings of the 2000 ACM SIGMOD international conference on Management of data (SIGMOD '00)*, New York, NY: Association for Computing Machinery, pp. 93-104.

where $N_k(X)$ is the number of points in the neighborhood of X (could be bigger than k , since multiple objects may have identical distance to X), $rd_k(X, O) = \{d_k(O), d(O, X)\}$ is reachable distance from X to O , $d_k(O)$ – k -distance or distance from object to the k -th neighbor and finally d some distance like Euclidean or L_p .

3. The local reachability densities are then compared with those of the neighbors using:

$$LOF_k(A) = \frac{1}{|N_k(A)| \cdot LRD_k(A)} \sum_{B \in N_k(A)} LRD_k(B)$$

which is Local Outlier Factor. A value of approximately 1 indicates that the object is comparable with its neighbors. A value below 1 indicates a denser region, while a value larger than 1 indicates outliers.

LOF detects local outliers rather than just global anomalies and works well in high-dimensional datasets. It can also identify more subtle deviations that traditional distance-based methods may miss. On the other hand, LOF are computationally expensive for large datasets due to k -NN calculations and requires fine-tuning of the k parameter, which affects sensitivity.

The algorithm is implemented in Python using:

```
sklearn.neighbors.LocalOutlierFactor.
```

5. DETECTING OUTLIERS IN INSURANCE DATA

In this section, we focus on detecting outliers in insurance data and claim incidents. The dataset used for analysis consists of 1000 individual claims, with the primary goal being to present insurance and incident information. The dataset includes 40 different attributes that describe each claim, categorised into four main categories: the insured person, their policy details, incident description, and characteristics of the involved car. The dataset is available on the Machine learning site as well as on GitHub⁶³². A Jupyter notebook with all calculations can also be found at the author's GitHub repository⁶³³.

If we want to compare the effectiveness of these two methods, we need a measure. Bearing in mind that the data set was intended for supervised machine learning

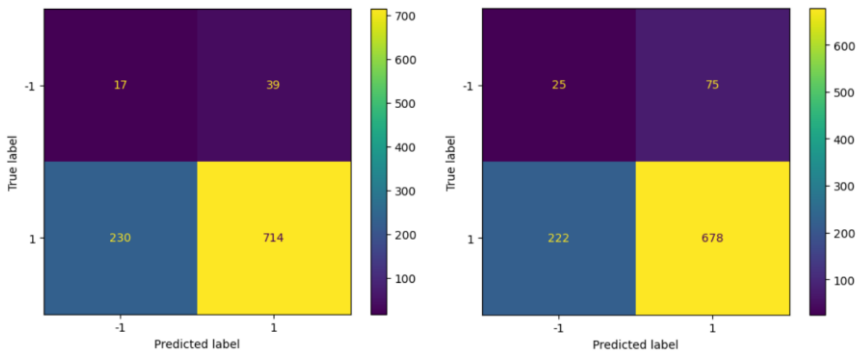
⁶³² https://github.com/RakeshHansrajani/Insurance_Data_Analysis/blob/main/insurance.csv

⁶³³ <https://github.com/dazdejkovic/Outlier-detection-1>

for fraud detection, we will use the column labelled ‘fraud’ to construct the confusion matrices.

In the process of data cleaning and preparation, correlated features as well as features with an almost uniform distribution were discarded. Also, only numerical features were used to make the methods comparable. The results in the confusion matrices were obtained by taking the optimal values of the model parameters. For example, for the LOF method, the optimal value of the parameter k (number of neighbors) is 60, while for the IF method, the optimal number of estimators (trees) is 500. On this data set, Isolation Forest proved to be a better method than the Local Outlier Factor method (the accuracy of the IF method was 73.6%, and the accuracy of the LOF method was around 71.13%). The next two figures show the confusion matrices for these two methods.

Figure 9. Confusion matrices for IF and LOF methods (-1 indicates anomaly)



Source: Author's calculations

Dealing with real data, an insurance expert should analyse each noted anomaly in detail and make the final judgment as to whether it is an anomaly or not.

* * *

While statistical techniques are useful for identifying outliers, they may not always be sufficient due to a variety of reasons:

1. *Complex patterns*: Statistical methods often rely on assumptions about the data, like normality or linearity. In real-world scenarios, datasets can have complex, non-linear relationships that simple statistical methods might not capture.
2. *Context dependence*: Outliers are highly context-sensitive. A value that is extreme in one context might be perfectly valid in another. Statistical

techniques may fail to incorporate domain knowledge or the context behind the data.

3. *Multidimensional data*: When working with multidimensional datasets, outliers might not be extreme in any single dimension but could still be unusual when considering all dimensions together. Statistical techniques often struggle with such cases.
4. *Robustness to noise*: Statistical methods can be sensitive to noise in the data. Noise might cause false positives, labelling valid data points as outliers, or false negatives, where true outliers go undetected.
5. *Dynamic datasets*: In datasets that evolve over time, such as streaming data, outliers might depend on temporal patterns. Statistical techniques designed for static data may not adapt well to these changes.

Machine learning methods have significantly advanced the detection of outliers, offering more robust and adaptive solutions compared to traditional statistical techniques. Here are some key advancements:

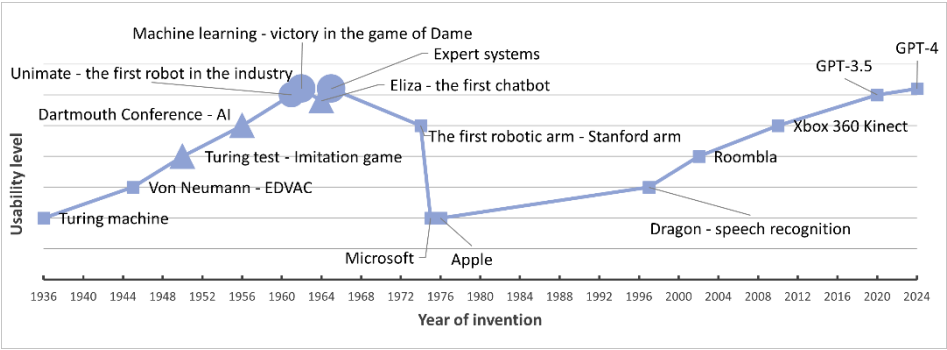
1. *Isolation forest*: This algorithm isolates anomalies by randomly selecting features and split values to create decision trees. Outliers, being rare and different, are isolated in fewer splits, making this method efficient and effective for high-dimensional data.
2. *Autoencoders*: These neural network-based models learn to compress and reconstruct data. Outliers are identified as data points with high reconstruction errors, as they deviate significantly from the learned patterns.
3. *Clustering techniques*: Methods like DBSCAN (Density-Based Spatial Clustering of Applications with Noise) identify outliers as points that do not belong to any cluster. These techniques are particularly useful for datasets with irregular distributions.
4. *One-Class SVM (Support Vector Machine)*: This method learns the boundary of normal data and flags points outside this boundary as outliers. It is effective for datasets with complex structures.
5. *Hybrid Approaches*: Combining machine learning with domain knowledge or statistical methods enhances the accuracy and interpretability of outlier detection. For example, integrating Isolation Forest with feature engineering tailored to the dataset.

These advancements have made outlier detection more scalable, adaptable, and applicable to diverse fields like fraud detection, network security, and healthcare.

ARTIFICIAL INTELLIGENCE SUPPORT FOR POLICYHOLDERS

Artificial intelligence, as a scientific field, is less than a century old. The idea and vision of creating beings or systems that mimic what nature has been creating for millions of years is much older. The study of human brain patterns and the formalisation of thinking and reasoning have inspired Egyptian engineers, Greek philosophers, and science fiction writers. Nevertheless, the point from which this very important period in the development of humanity begins is the Universal Turing Machine, the concept of which was presented in 1937. A few years later, in 1956, at Dartmouth College in America, this area received its official name. A group of already experienced researchers in this field organised a conference where the previous achievements and future directions of development were discussed. At the suggestion of American scientist John McCarthy, winner of the Turing Award and creator of the LISP programming language, the field was named Artificial Intelligence (AI).

Figure 1. The most important events in the development of artificial intelligence presented chronologically and by intensity of importance



Source: Author's research

The history of the development of this field does not have continuous growth, but is very dynamic, from great successes and strong enthusiasm in certain decades to a period with great scepticism and almost halting development. Sometimes the reasons are technical limitations, and sometimes political and economic conditions. Figure 1 presents the most important events in the short history of AI. Squares represent innovations or projects that were the drivers and basis for a

series of other innovations, triangles are innovations that remained at the level of prototypes or models for practice and further upgrading. Circles represent AI innovations that have seen practical application.

Everything starts with a theoretical concept in 1936-1937 when an abstract computing machine was presented that consisted of unlimited memory and a scanner that moved back and forth through the memory, symbol by symbol, reading what it found and then writing down further symbols. The scanner's actions were dictated by a program of instructions that were also stored in memory in the form of symbols. This is Turing's concept of the stored program, whereby the machine had the ability to run on its own program and thus modify and improve it, which is now known as the Universal Turing Machine.⁶³⁴

Unlike traditional Natural Language Processor (NLP) models that rely on hand-crafted rules and hand-marked patterns, Large Language Models (LLM)⁶³⁵ process huge amounts of textual data and establish relationships between words in the text. These models have advanced over the past few years thanks to advances in computing power. LLMs improve their ability as the size of their input datasets and training algorithms increases. Machine learning is responsible for training algorithms. Machine learning is by far the most developed and widely used model of artificial intelligence. It is intended to develop systems that improve their performance with experience. Typically, a combination of unsupervised, supervised, and reinforcement learning is used throughout the development phases of a new robot. The most advanced branch of machine learning is deep learning. Deep learning involves the creation of neural networks, inspired by the biological neurons in our brain. By structuring algorithms in layers, this model creates an artificial neural network that can learn by itself and make intelligent decisions. Deep learning combined with Big Data is the driving force for many applications in artificial intelligence, such as object recognition, speech, natural language processing, etc.

The main star of the current period is ChatGPT. In June 2020, the third version of the GPT algorithm, GPT-3, was released. It's a model that uses deep learning to create code, poetry, and other similar language and writing tasks. This version was free to use and gained popularity at an incredible speed. This was followed by the GPT-4 version, additionally improved, which, among other things, has up-to-date information, which the previous version did not have. While not the first of its kind, it is the first to create content that is almost indistinguishable from

⁶³⁴ <https://www.britannica.com/biography/Alan-Turing/Computer-designer>

⁶³⁵ Menor, D. (2023). *Veliki jezički modeli: sve što trebate znati*.
<https://hashdork.com/bs/veliki-jezički-modeli>

human-generated content. It gained its incredible popularity through applications such as chatbots, translators and other programs that use natural language. The key thing about this technology is, apart from quality, easy availability and ease of use.

Given that AI has become an active component of everyday life and is faster and more accurate than humans in many things, the question of ethical application arises. Important figures in the AI of our age, such as Elon Musk, Stephen Hawking, Steve Wozniak and over 3,000 others, have signed an open letter to all world governments prohibiting the development and subsequent use of autonomous weapons for purposes of war.

However, there are still experts in the field who are so concerned about the future of AI that they even demand a moratorium on the further development of GPT. Max Tegmark,⁶³⁶ physicist and artificial intelligence researcher at MIT, author of the book *Life 3.0*, works intensively to raise awareness among people regarding the consequences that AI can have on humanity if it is developed and implemented unethically or insufficiently carefully. Tegmark believes that life 3.0 has not yet been created and implies a life that, in addition to being able to change its software, will have the ability to recreate hardware as well. He also claims: "Most politicians don't even have this on their radar. They think maybe in 100 years or whatever. Right now, we're at a fork in the road. This is the most important fork humanity has reached in its over 100,000 years on this planet. We're building effectively a new species that's smarter than us."⁶³⁷

Has any AI machine passed the Turing Test?

The Turing Test is a measure of a machine's ability to exhibit intelligent behaviour that is indistinguishable from that of a human. In this test, a human evaluator interacts with both a machine and a human through a computer interface. If the evaluator cannot reliably distinguish between machine and human responses, then the machine is said to have passed the test and demonstrated human-like intelligence. The Turing Test was a fundamental concept in the philosophy of artificial intelligence and its potential capabilities.

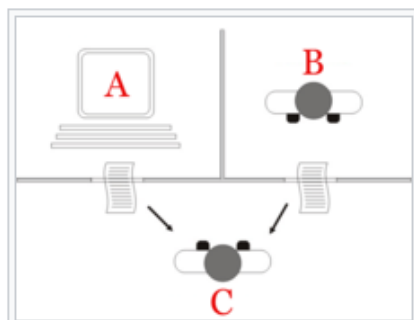
To test the machine's intelligence, a human (hidden entity C) would communicate with the machine (A) or another human entity (B) via text messages. Figure 2 shows a Turing test taking place in a controlled environment, where a hidden

⁶³⁶ <https://youtu.be/VcVfceTsD0A>

⁶³⁷ Tegmark, M. (2020). *Život 3.0: kako biti čovek u doba veštačke inteligencije*. Belgrade: Laguna.

human entity B, an AI machine A, and an average human examiner C are unaware of each other's identities.

Figure 2. The Turing test



Source: https://sr.wikipedia.org/sr-el/Turingov_test

Assessors (C) sitting in another room conduct the interviews and have five minutes of interrogation to determine which messages are coming from the machine and which are from a human. If a machine can fool 30% of human examiners, it is considered to have passed the Turing Test.

While the Turing Test may seem simple, it encompasses a lot of complexities that an AI system must navigate: natural language processing, context awareness, and even elements of emotional intelligence. Moreover, the test challenges the underlying algorithms to understand idiomatic expressions, sarcasm and rhetorical questions, as well as the nuances inherent in human communication. Over the years, the Turing Test has been criticized as an inadequate measure of all forms of intelligence. Critics argue that passing the Turing Test may require mere mimicry of human reactions rather than deep understanding or awareness. Nonetheless, it remains an influential benchmark in the AI community due to its emphasis on indistinguishable human-machine interaction. It is also important to remember that the Turing test does not cover all representations of the concept of intelligence. For example, a certain machine might beat a human at chess, but it wouldn't be able to pass a five-minute test.

Two researchers from the University of San Diego's Department of Cognitive Sciences published a paper titled "People cannot distinguish GPT-4 from a human in a Turing test"⁶³⁸ describing a Turing Test conducted where GPT passed with an unexpectedly high score. This is why ChatGPT is a prime candidate for

⁶³⁸ Jones, C., & Bergen, B. (2024). *People cannot distinguish GPT-4 from a human in a Turing test*. Cornell University.

the implementation of artificial intelligence in the field of insurance customer support.

In early 2025, Chinese AI startup DeepSeek caught the world's attention with its free AI chatbot, which looks and works very similar to ChatGPT. The company DeepSeek claims that they managed to build a product equal to ChatGPT-4 with an incomparably lower budget than the one announced by Sam Altman, head of OpenAI. In addition, this application uses less memory than its rivals, which ultimately reduces resource consumption on the user side. That combination of performance and lower price helped DeepSeek's AI assistant become the most downloaded free app in Apple's App Store when it was released in America. Like previous Chinese AI models, DeepSeek is trained to avoid politically sensitive issues.

It is expected that the adaptation of AI in Europe can significantly contribute to the growth of the industry that has the greatest scope for development or the greatest costs. The assessment is that the greatest potential is in consumer goods trade, followed by construction, transport and advanced manufacturing. Significantly smaller, but still visible, is the impact on insurance, telecommunications and agriculture.

1. HOW CAN AI HELP INSURANCE COMPANY CUSTOMERS?

Insurance company clients as natural persons can get better information, faster and simpler processes, lower costs and better protection thanks to artificial intelligence, while improving their everyday insurance experience. Artificial intelligence can indirectly help insurance company customers in a number of ways by improving the insurance company's service through the incorporation of AI.

Personalized risk advice and recommendations for choosing the right cover can be provided by AI based on the analysis of user data (e.g. demographic information, lifestyle, driving habits) and suggest the policy that best suits their needs. Also, policyholders can receive recommendations, such as the introduction of safety measures in houses, apartments and premises where they have their own small business, as well as advice on safer driving.

Faster and simpler processing of claims by speeding up the process and reducing paperwork can be achieved by introducing artificial intelligence into the processing of documentation from the claim report and images (e.g. vehicle damage) in real time. In this way, clients no longer have to wait a long time for the approval of claims for compensation. Also, AI can help the injured party by

automatically filling out the forms used in the claims report based on previous entries, thus saving time.

Smart assistants and chatbots increase the availability and accessibility of the insurance company outside of working hours. Virtual assistants using artificial intelligence, such as ChatGPT, can provide answers to frequently asked questions at any time and help users understand their policies, submit claims or find out all the details about possible coverages. These tools facilitate communication even for users who do not know the technical terms of the insurance field or are not familiar with the processes of insurance companies.

Prevention of problems by health status monitoring and proactive support by sending alerts can be provided thanks to useful notifications, from a system supported by artificial intelligence, that policyholders can receive in real time. It can be, e.g. warning of severe weather that could threaten their property, with advice on precautionary measures. AI connected to wearable devices can alert users to changes in health parameters and suggest immediate measures to eliminate potential health hazards, while aligning the renewal policy with their health status.

Easier and more cost-effective insurance policy management with AI-powered applications where policyholders can easily update their details, track the status of their claims and renew policies through simple AI digital platforms. Also, such applications can analyze current customer policies and suggest ways to reduce costs and improve coverage adequacy, e.g. by switching to a different insurance package.

Reducing insurance costs by introducing dynamic policy pricing and rewards for less risky behaviour can be achieved by letting AI adjust insurance prices based on customer behaviour, such as driving safely or adopting recommended risk reduction measures. Also, the insurance company can introduce discounts for customers who, for example, drive carefully or maintain their property according to the advice of the AI system.

Greater policy transparency and personalized education can be achieved by AI by explaining complex aspects of policies to policyholders in plain language. Clients thus receive customized guides to understand their rights and obligations in relation to insurance.

2. HOW AI COULD SUPPORT BROKERS TO HELP POLICYHOLDERS?

Brokers in their daily work collect a large amount of structured and unstructured data about risks, policies, claims, etc. Management of images, documents printed from various information systems, handwritten documents, scanned documents, filled electronic forms, etc., is very demanding and time-consuming for brokers. Artificial intelligence can simplify a broker's complex operations in a number of ways.⁶³⁹

Efficient data extraction and management using AI tools that use technologies like optical character recognition (OCR) and natural language processing (NLP) to collect data from a variety of sources, including website forms, customer conversations, email and social media posts. After collecting data, AI helps organise its storage and provides easier access to this data, allowing brokers to efficiently manage large amounts of information.

Continuous product improvement using machine learning and advanced algorithms. AI enables brokers to understand customer behaviour and preferences, leading to the personalisation of insurance policies. Also, by gathering feedback and analysing the market, AI identifies operational obstacles and product limitations, driving continuous service improvement.

Risk detection and mitigation using AI systems that analyse data from a variety of sources, including demographic information, claim history and external factors like economic conditions and weather patterns, to identify potential risks before they become a real insurance problem. These predictive models help brokers come up with risk mitigation strategies, such as dynamic policy pricing.

Building customer relationships by automating data storage and analysis. So, AI allows brokers to focus on building personal relationships with clients. AI tools improve transparency and personalisation of services, leading to greater customer satisfaction and loyalty.

Improving fraud detection and claims processing using AI technologies, including machine learning, which can analyse patterns of behavior and identify suspicious activity, improving fraud detection. Also, automating the claim settlement process reduces processing time and increases accuracy, which contributes to the efficiency of operations.

⁶³⁹ Open GI (2024). *Three Ways AI Can, and is, Transforming Broking*.
<https://opengi.co.uk/blog/three-ways-ai-can-and-is-transforming-broking>

Artificial intelligence is already part of insurers' information systems using big data and algorithms, as it enables them to automate risk underwriting, claims decisions and improved business processes. An increasing number of underwriting decisions are being automated, so the new role of the broker is to negotiate with the insurance company on behalf of the client, in case the computer rejects his request.⁶⁴⁰ Brokers can supplement the data collected by AI by adding layers of data that are not readily available, such as business culture and its approach to risk management.

There is a risk for brokers that automation and big data could marginalise brokers dealing with specific types of products, as is already happening in the home insurance and travel insurance markets. The introduction of autonomous vehicles could fundamentally change car insurance. Safer AI-driven driving in autonomous vehicles could lead to lower premiums and lower claims, reducing the overall premium income generated by the sector and thus the commission to brokers. Advances in the Internet of Things will have an impact on health insurance as it leverages data obtained from wearable technology, connected personal devices and technology in the home.

It is possible that these technological advances will bring risk to brokers in the commercial insurance sector, where brokers are traditionally more represented. Since people's behaviour is one of the biggest risk factors in insurance, the introduction of smart manufacturing processes and monitored inventory warehouses could reduce human errors in factories and warehouses and reduce premiums accordingly.

The application of artificial intelligence allows insurance brokers to streamline operations, increase efficiency and improve the customer experience. Using insurance software solutions with elements of artificial intelligence makes the insurance industry more accessible to customers. A combination of advantages, such as efficient data management, continuous improvement of products and services, proactive detection and mitigation of risks, as well as building relationships with clients, will accelerate the growth of the broker's business. Also, brokers will more easily perform their roles without feeling overwhelmed by numerous administrative activities. However, brokers will face the challenge of keeping up with technological advances, adopting new knowledge and techniques for risk management. Finally, brokers may be under additional pressure to prove their value in the insurance distribution chain.

⁶⁴⁰ Jenkin, A. (2018). *Artificial Intelligence and Insurance Broking*. Russell Scanlan, Nottingham's insurance broker, <https://www.russellscanlan.com/blog/artificial-intelligence-and-insurance-broking>

3. CHALLENGES THAT AI PRESENTS TO THE CONCEPT OF INSURANCE

Insurance works by pooling the risks of similar independent units of exposure, which allows insurers to use the law of large numbers in a variety of ways. New technologies can help answer the question of whether there are enough similar units to cover. In the simplest case where the law of large numbers applies, it is assumed that the risks are similar and independent of each other. In reality, this is often not the case because it is difficult to find identical risks; that is, most often, the risks are just similar and then different insurance prices correspond to them. Also, risk independence is not complete. AI can be valuable in verifying the mutual independence of risks. All entities nowadays are increasingly networked, which means that a risk that materializes somewhere can cause widespread collateral damage in other parts of the networked world. This phenomenon is not only related to cyber risks, although they are certainly a central theme in the risks that spread in computer networks. In the years to come, insurers will have to deal with the increasing dependence between different risks. AI will be a tool to help insurers understand such risk interdependencies. AI risk analysis tools significantly reduce the imprecision of adverse event probabilities, but even when probabilities are more accurately predicted, outcomes are still stochastic. This can be used to calculate the risk-based premium individually for each risk.

The claim is, by definition, a loss that occurs at a known time, in a known place, and from a known cause. The key elements in predicting an insurance claim are the probability of occurrence and the cost of the claim. Insurers' appetite is generally greater for cases that have less forecast error, as this results in better portfolio management, more accurate pricing and easier claims handling. The occurrence of an event depends on how the event is defined and how it is covered. Probability of loss is generally an empirical exercise and deals with the problem of predicting the occurrence of loss with sufficient accuracy. The cost of claim determines the insured loss, that is, the ability of the insurer to make an objective assessment of the amount of compensable loss that occurs as a result of the claim of the person who owns the insurance policy and has proof of the loss covered by that policy. New technologies can reduce prediction error and thus increase insurance coverage. Innovative solutions, such as the collection of large amounts of data, the application of the Internet of Things and artificial intelligence methods, help to improve the prediction of claims and add value to actuarial pricing methods. The insured event that causes claims should be an accidental loss in an event beyond the control of the insured. New technologies do not fundamentally change this scenario. Another thing to note is that, traditionally, the insured has an advantage over the insurer in terms of knowing the own risk.

This balance could change, as AI and big data will give insurers better tools to estimate the likelihood of occurrence and magnitude of loss. Insurance premiums should cover not only the expected costs of the claims, but also the costs of issuing and administering the policies, claims settlement, the costs of capital of the insurance company, and finally provide a dividend to the insurance company's shareholders.

Insurers mainly deal with the following risks, which are characterized by different frequencies and severities of events:

- high frequency of small losses and
- low frequency of large losses.

The frequency of events has a significant impact on the predictability of losses, and subsequently on the level of expected losses and compensation for capital or risk. Again, in this area, new technologies can improve insurance by making valuations better. Although AI could be useful for looking at low-frequency, high-loss events, the high economic value of the resources involved means that very precise risk analysis and underwriting are already possible in this area. Thus, AI can be expected to have a far greater impact on the risk of high-frequency small losses. In this area, overheads arising from various claims administration tasks can effectively render risks uninsured. AI and related new technologies have the potential to increase the efficiency of insurers' processes. In a competitive market, this should lead to lower premiums for insuring the risk of the high frequency of small losses in practice. A risk is insured only if the insurer can charge an affordable premium from the client's point of view. If the probability of an insured event occurring is so high, or the cost of the event so significant, that the premium is disproportionately large in relation to the amount of protection offered, it is unlikely that anyone will buy insurance unless legally required to do so.

Insurance can be threatened by issues such as adverse selection, moral hazard, and insurance fraud.

Anti-selection describes a group that is populated with a higher average level of risk than was predicted when the insurance product was designed. This can happen because less risky policyholders leave the company when they feel the premiums are unreasonably high for their risks, and only high-risk policyholders remain. Adverse selection can occur in a situation where the prices are correct, but the market conditions are not favourable, i.e. another insurer offers lower prices due to different risk segmentation or when potential clients decide not to take insurance at all. New technologies can help the insurer avoid adverse selection with the help of improved tools that lead to better risk differentiation

and then set premiums that match the actual risk. Pricing accuracy reduces the danger that only bad risks will remain in insurance. However, it should be added that AI may ultimately favour platforms that increase the possibility of adverse selection, as such systems can monitor the offer of different insurers in real time and select the best offer for each client. This can lead to a situation where the insurer's portfolio is grouped with higher risks than expected. Initiatives such as Open Finance and Open Insurance should also be seen in this context.

Moral hazard describes the scenario of the policyholder's behaviour becoming less cautious towards the risk for which there is coverage. New technologies are likely to improve the tools an insurer has at hand to control moral hazard.

Insurance fraud differs from moral hazard in that it refers to the intentional actions of the insured, which were done with the aim of obtaining an illegal benefit at the expense of the insurance company. New AI tools can help a lot in the fight against insurance fraud. At the same time, it should be emphasised that new technologies can also be of great benefit to those who want to commit insurance fraud. Criminals can develop effective automated systems based on artificial intelligence to commit insurance fraud against insurers.

Finally, it should be understood that insurance is not a static concept that remains the same over time. Insurers have developed a range of solutions to adapt insurance techniques to meet different challenges. AI can be used in loss prevention to limit risks to a tolerable level. Insurers can use AI systems to inform their customers about how to protect themselves against the risks that are realized. This will be especially true in the world of the Internet of Things, where continuous preventive behaviour will be possible. Adjustments to terms can also play a role in this, as for example deductibles can combat moral hazard, while coverage limits can transform unquantifiable underlying risks into known maximum exposures.

When the commercial insurance market fails to provide coverage for a critical risk, private-public partnerships are established.

4. EXAMPLES OF THE USE OF AI FOR CUSTOMER SUPPORT IN INSURANCE AROUND THE WORLD

AI is helping the insurance industry make optimal use of vast amounts of data. Insurers are using artificial intelligence to create individualized policies, automate underwriting processes and provide valuations with greater accuracy to clients around the world. Insureds especially benefit from shopping with

aggregators that compare coverage and prices from various insurers, fast claims processing, 24/7 insurance service and improved decision management.

Reducing price bias

Arity⁶⁴¹ is an Insurtech company that processes and analyses data in the transportation industry. The company was founded by a large American insurance company, The Allstate Corporation, in 2016. It collects and analyses massive amounts of data, using predictive analytics with the goal of making transportation smarter, safer, and more useful for everyone. Artificial intelligence analyses trillions of miles of driver data, looking for results that can be used to improve safety,, e.g. through usage-based auto insurance programs, which allow drivers to pay a premium commensurate with the amount and level of safety of their driving.

Assessment of damage to the vehicle

Major American insurance company Liberty Mutual is exploring artificial intelligence through its Solaria Labs⁶⁴² initiative, a cross-functional team that develops new advanced products and services to better serve customers and partners. The result of Solaria Labs' experimentation in the fields of computer vision and natural language processing is the AI tool Auto Damage Estimator. By conducting comparative analyzes of anonymous claim photos, this AI tool is able to quickly assess vehicle damage and provide the injured party with a realistic estimate of the time and cost of repairing the vehicle after an accident.

Real-time customer service representative training

Hi Marley⁶⁴³ It is a platform purpose-built for the insurance industry to make it easier for policyholders to reach the right insurance company representatives, reducing communication inefficiencies. Hi Marley uses a cloud platform equipped with AI features to ensure that customer service representatives work as quickly as possible. For example, Hi Marley's platform translates text into different languages to adapt to the customer and provides real-time training to contact centre operators to improve interactions with policyholders.

⁶⁴¹ <https://arity.com>

⁶⁴² <https://www.solarialabs.com>

⁶⁴³ <https://www.himarley.com>

Matching customers with the best customer service representatives

Affinity⁶⁴⁴ is a leading provider of artificial intelligence that helps insurers develop better relationships with their customers. It uses patented AI technology to match participants in customer interactions. Improves the quality of customer conversations by matching callers with customer service representatives based on best fit, not call order. With access to vast data, the company's AI technology determines patterns of human behaviour and matches contact centre operators with callers based on that. By pairing people who communicate more easily with each other, insurance companies have the ability to form stronger relationships with clients.

Communicating with customers in different languages

Avaamo⁶⁴⁵ is an advanced generative AI platform that enables global enterprises to automate and deliver outstanding customer communication experiences. Their AI technology includes voice transcription, natural language understanding and generative artificial intelligence. It supports self-service customer service interactions for leading global companies in 114 languages. Avaamo seamlessly integrates with many common business applications and simplifies processes for insurance providers. Insurance providers with a broad customer base can rely on Avaamo to reduce the time it takes to create quotes, submit claims and underwrite policies for customers from different parts of the world.

5. POSSIBILITIES OF APPLYING ARTIFICIAL INTELLIGENCE IN INSURANCE IN SERBIA

Insurance companies, similar to other companies, in our area are not yet ready to accept advanced work techniques using artificial intelligence on a larger scale, despite claims that they would reduce costs, save time and solve the issue of labour shortages. Last year was marked by the appearance of the first easily accessible and very useful tool that uses the artificial intelligence of ChatGPT. Apart from being a valuable help in various tasks that employees deal with, there have not been many organised implementations of ChatGPT in business processes in our market.

A survey by the American company IDC, which is a leading global market researcher, data analyst and organizer of events in the world information technology market, conducted in April 2024, showed that only 12.5% of started

⁶⁴⁴ <https://www.afiniti.com>

⁶⁴⁵ <https://avaamo.ai>

IT projects using artificial intelligence in the previous year were completed. It remained unclear which part of such a small number of completed projects was really successful from the business perspective of the companies that implemented them.

The introduction of artificial intelligence in the company makes sense only if the following conditions are met: processes are organised with detailed procedures, data is digitised to the level that what is not entered into the information system does not exist, and all business processes are maximally automated. Only then does artificial intelligence achieve its best results. Unfortunately, all these conditions are rarely met in our companies. Estimates are that only about half of the companies in Serbia are significantly digitised, which means that a large number of companies should first invest effort in the process of digitisation and automation, and then move on to advanced techniques such as artificial intelligence. Company data is often poorly organized on servers and often not in a form that artificial intelligence can exploit. However, investment in data management more often goes to IT security and personal data protection due to strict regulations than to transforming data to work with AI and increasing data quality, which further slows down the future implementation of artificial intelligence. As a rule, training of artificial intelligence models is done in the most common languages such as English, while the Serbian language, as well as other languages that do not use the Latin alphabet, are less often used for training these models, so the results achieved by AI in such languages are significantly less reliable.

The successful implementation of artificial intelligence requires a strategic approach: a high-quality expert team, a detailed policy for the use of AI tools, and enabling a large number of employees to attend AI courses in order to become familiar with this field. Very few companies in this region have adopted their own strategy for the development of artificial intelligence in business processes, among other things, because this technology is developing quickly, and it is difficult to plan when you do not know what will be current in the AI world next year.

In addition to the unreadiness of our companies to implement AI projects, there are also objective circumstances that make implementation difficult.⁶⁴⁶ Few developers know how to work in this area. The costs of implementation are high, which leads to high prices and the unprofitability of these projects, that is, the inaccessibility of AI projects to a large number of companies. The IT

⁶⁴⁶ Dowd, A. (2024). The Impact of AI on the Role of the CIO. *IDC CIO Summit presentation*, Savudrija, Croatia.

infrastructure in companies that want to implement artificial intelligence often cannot support the desired performance of the future AI system. Coordination between business and IT in companies is often not at a high enough level, so it is not possible to overcome misunderstandings in complex projects where AI is used. Also, members of the top management responsible for IT often have other priorities: the digital transformation of the company, the modernization of the IT environment with the aim of meeting the growing demands of the business, the management of IT risks and often the most important optimization of IT costs. These priorities simply prevent IT decision-makers from dealing with artificial intelligence.

6. APPLYING AI TO HELP UNDERSTAND INSURANCE PRODUCTS AND COVERAGE USING ChatGPT AS AN EXAMPLE

ChatGPT can provide significant assistance in understanding insurance products and coverage. The following examples show how ChatGPT has helped in specific situations. Some answers are partially shortened to save space in the work.

Explanation of basic terms and types of insurance

ChatGPT helps in understanding basic concepts like premium, coverage, deductible, policy, risk and more. Can accurately explain the difference between different types of insurance and different products of the same type of insurance. To begin with, he was asked a question to which not many people know the answer, but it is easy to find the answer on Internet search engines.

Question: "Why is the amount of money that the insured pays to the insurer in exchange for risk coverage called a premium?"

ChatGPT's response: "The term 'premium' in the context of insurance comes from the Latin word *praemium*, which means 'reward' or 'payment in advance for a service'. In the context of insurance, a premium refers to an amount paid by the insured to the insurer as consideration for assuming the risk and providing the insurance protection. Thus, the name 'premium' emphasises the specific nature of this payment - a pre-agreed amount by which the insurer is compensated for providing the protection and assuming the risk."

After the correct answer from the theory, a practical question was asked about a product of a specific insurance company.

Question: "What is covered by the insurance policy My warm nest Globos insurance company from Belgrade?"

ChatGPT's response: "The 'My Warm Nest' insurance policy from Globos insurance company from Belgrade provides comprehensive protection for your home, including residential property (insurance covers damage to your apartment or house caused by various risks), household items (includes coverage for damage or loss of personal belongings inside the home) and ancillary facilities (the policy includes insurance of ancillary facilities such as garages). This policy protects your home, its contents and ancillary facilities against unforeseen events. For more detailed information on covered risks and insurance conditions, it is recommended to visit the official website of Globos Insurance or contact their representative directly."

Detailed interpretation of policy coverage

ChatGPT can analyse the standard terms of an insurance policy, explain what is specifically covered by the insurance and what is not, explain what is excluded and interpret specific clauses or add-ons in the policy. A question was raised about the coverage of water spill risk from the standard property insurance terms, and received a response at the standard human customer support level of the insurance company's contact centre.

Question: "In the case of water damage that leaked from the dishwasher and destroyed furniture in an apartment covered by a household insurance policy, will the insured receive compensation?"

ChatGPT's response: "In the case of water damage that has leaked from a dishwasher and destroyed furniture in an apartment, whether the insured will receive compensation from the household insurance policy depends on the specific terms and coverage provided by the policy. Household insurance policies often cover damages caused by water leaks from various appliances in the apartment, including dishwashers, washing machines, refrigerators and other appliances that use water. However, this depends on the specific policy, so it is important to check whether the damage is caused by an exit water from the dishwasher (e.g. due to machine failure or poor installation). Many policies cover leakage or leakage from the appliance, but check that this is explicitly included in the terms. If damage from water leaking from the dishwasher is not excluded from coverage in the policy terms, the insured will likely be compensated for the destroyed furniture, subject to possible application of deductibles, copayments or other limits. It would be best to check the specific terms of your home insurance policy, as policies vary in terms of coverage and exclusions."

Simulation of the execution of bureaucratic procedures in claims

ChatGPT explains how the payment of damages works in specific situations (e.g. traffic accident, property damage, medical expenses) and provides guidance on how to proceed in the event of an insurance claim. The question was asked to explain the procedure of a particular insurance company. In the answer, ChatGPT used general knowledge in combination with specific data for the website and phone number of the specific company.

Question: "How should a driver whose vehicle has been hit by another vehicle that has a motor third-party liability insurance policy with Dunav insurance company report the damage?"

ChatGPT's response: "If you are a driver whose vehicle has been hit by another vehicle that has a motor third-party liability insurance policy with Dunav Insurance, the claim process depends on the circumstances of the accident. Here are the steps you should take:

Steps for reporting damage to Dunav Insurance

- a) Collecting evidence at the scene - Immediately stop the vehicle and secure the scene of the accident. If there are injuries, call the ambulance (194) and the police (192). Photograph the damage to both vehicles and the scene of the accident. Write down details of witnesses, if any.
- b) Filling out the European report or calling the police - If there are no injuries and both drivers agree on the circumstances of the accident, you can fill out the European report on a traffic accident. If there is a discrepancy, serious damage or injuries, be sure to call the police, as their records will be needed to report the damage.
- c) Report the damage to Dunav Insurance - The owner of the damaged vehicle should report the damage to Dunav Insurance, but you can also help in the process. Damage can be reported in person at the Dunav Insurance branch office, online through the website: www.dunav.com or by phone at the contact centre number: 0800 386 286. Required documents for application: completed European report or police report, traffic license and driver's license, insurance policy of the vehicle that caused the damage and photos of the damage to the vehicle and the scene of the accident.
- d) Damage assessment and payment - Dunav Insurance will organize a damage assessment. The injured party can receive compensation or repair the vehicle in authorised service centres. After the solution, the payment is made to the account of the owner of the damaged vehicle or service.

If you have additional questions, it is best to contact Dunav Insurance directly for accurate information about your case."

Education about the rights and obligations of the policyholder

ChatGPT helps users understand their rights and obligations towards the insurer and explains what the insurance company can ask for and receive from the insured and vice versa. In the following answer, ChatGPT showed a clear understanding of the Law on Obligations from the SFRY period, which is still valid in Serbia, and the behaviour in the domestic practice of the insurance industry.

Question: "What can the insured do if the insurance company decides to increase the annual instalment of multi-year kasko insurance?"

ChatGPT's answer: "If the insurance company decides to increase the annual instalment of multi-year kasko insurance, the policyholder has several options:

- a) Check the terms of the contract - look at the insurance policy and the general conditions you signed. Multi-year kasko insurance contracts often provide for the possibility of premium adjustments, but the insurer must clearly state the reasons.
- b) Contact the insurance company - Ask for a written explanation of the premium increase. Ask about the possibility of keeping the old price or getting a discount.
- c) Compare offers from other insurers - Check prices from other insurance companies. If you find a better deal, you may consider switching to another insurer.
- d) Terminate the contract without penalty (if possible) - If the contract does not have a premium increase clause, you can request the retention of the old price or termination without penalty. If there is a premium increase clause, check if there is an option to get out of the contract.
- e) File a complaint or complaint - if you think the increase is not justified, you can file a complaint with the insurance company. If you do not get a satisfactory answer, contact the National Bank of Serbia, which supervises the work of insurance companies.
- f) Tip - If you pay the premium in instalments, do not stop the payment before checking the consequences. Always ask for written confirmation of the terms and any changes to the policy."

Simple and fast communication

ChatGPT answers questions in real time, providing information in simple language that even teenagers can understand. It speaks your language and can simulate the role of an insurance advisor, explaining complex information in an easy-to-understand way. It is best to check in practice at <https://chatgpt.com> how ChatGPT answers questions, explaining complex insurance information in an easy-to-understand way.

PREDICTING HIGH-VALUE INSURANCE POLICYHOLDERS USING RFM CLUSTERING AND SVM CLASSIFICATION

Customer relationship management (CRM) is a cornerstone of modern business strategies, particularly in the highly competitive insurance industry. By enabling companies to segment policyholders based on their behavioural patterns and value contribution, CRM facilitates targeted marketing efforts, enhances customer retention, and optimises resource allocation.⁶⁴⁷ Among the diverse pool of insurance policyholders, predicting those who generate the highest long-term value, referred to as high-value customers, is a critical task for insurers aiming to maximise profitability and strengthen client loyalty. Traditional approaches to customer segmentation, however, often rely on manual analysis or simplistic heuristic rules, which lack scalability and fail to capture the complexity of customer behaviour in large datasets.

The advent of artificial intelligence (AI) and data mining techniques has revolutionised the way businesses approach customer segmentation and predictive analytics. Data-driven methods, such as clustering and classification, offer a systematic and automated means to uncover hidden patterns in customer data and forecast future behaviours.⁶⁴⁸ Clustering techniques, such as the widely adopted k-means algorithm, group customers into homogeneous segments based on key behavioural attributes, while classification models, such as Support Vector Machine (SVM), enable the prediction of segment membership for new or prospective customers based on independent variables.⁶⁴⁹ These methods have been successfully applied across industries, including retail, banking, and telecommunications, to identify high-value customers and tailor marketing strategies accordingly.⁶⁵⁰

⁶⁴⁷ Kotler, P., & Keller, K. L. (2016). *Marketing management*, 15th ed., Pearson Education.

⁶⁴⁸ Han, J., Kamber, M., & Pei, J. (2011). *Data mining: Concepts and techniques*, 3rd ed., Morgan Kaufmann.

⁶⁴⁹ Cortes, C., & Vapnik, V. (1995). Support-vector networks. *Machine Learning*, 20(3), pp. 273-297.

⁶⁵⁰ Ngai, E. W. T., Xiu, L., & Chau, D. C. K. (2009). Application of data mining techniques in customer relationship management: A literature review and classification. *Expert Systems with Applications*, 36(2), pp. 2592-2602.

In the context of insurance, prior research has underscored the utility of Recency, Frequency, and Monetary (RFM) analysis—a well-established framework in marketing analytics—for evaluating customer value.⁶⁵¹ Recency measures the time since a customer's last interaction or purchase, Frequency captures the regularity of transactions, and Monetary reflects the total financial contribution of the customer. By integrating RFM attributes into clustering models, insurers can effectively categorize policyholders into distinct groups, ranging from low-value or inactive clients to the most profitable high-value segment. Furthermore, coupling RFM-based clustering with classification techniques allows for the development of predictive models that generalise these insights to new datasets, enhancing scalability and operational efficiency.

This study proposes a methodology for predicting high-value insurance policyholders using RFM clustering and SVM classification. Using a real-world insurance dataset, we first apply k-means clustering to segment customers based on their RFM attributes, isolating the high-value cluster of policyholders. Subsequently, we train an SVM classifier using demographic, vehicle-related, and policy-specific features to predict a customer's cluster membership. This dual approach not only provides a robust framework for customer segmentation but also offers an automated, accurate, and scalable solution for insurers seeking to prioritise their most profitable policyholders. The findings contribute to the growing body of literature on data mining applications in CRM and offer practical implications for insurance companies aiming to refine their customer management strategies.

The remainder of this paper is organized as follows: Section 1 reviews the relevant literature on customer segmentation and predictive modeling in the insurance industry, grounding the study in established methodologies; Section 2 outlines the data and methodology, including data preprocessing, clustering, and classification steps; Section 3 presents the results and evaluation metrics; and Section 4 discusses the implications of the findings for insurance companies.

1. LITERATURE REVIEW

Customer segmentation and predictive modelling are pivotal in customer relationship management (CRM) and direct marketing, particularly within the insurance industry, where understanding customer value drives strategic decision-making. Traditional statistical approaches, such as regression and probit

⁶⁵¹ Fader, P. S., Hardie, B. G. S., & Lee, K. L. (2005). RFM and CLV: Using iso-value curves for customer base analysis. *Journal of Marketing Research*, 42(4), pp. 415-430.

models, often falter when confronted with the heterogeneity and complexity of customer data, resulting in suboptimal segmentation accuracy.⁶⁵² In response, machine learning techniques—namely clustering and classification—have gained prominence as robust alternatives, offering enhanced precision and scalability in identifying distinct customer segments.⁶⁵³

Several studies have leveraged clustering techniques to address customer segmentation challenges in insurance. Xiahou et al. applied k-means clustering followed by decision tree analysis to segment car insurance customers based on profitability metrics. Their approach successfully delineated profitable customer groups, enabling insurers to tailor offerings; however, it lacked a predictive component to classify new policyholders dynamically.⁶⁵⁴ Similarly, Verhoef and Donkers employed a probit model to classify insurance customers into high- and low-value segments based on potential lifetime value. While innovative for its time, their model achieved a modest classification accuracy of 52%, underscoring the limitations of traditional statistical methods in capturing nuanced behavioural patterns.⁶⁵⁵

The evolution of machine learning has spurred the development of hybrid methodologies that integrate clustering with predictive modelling to overcome these shortcomings. Fang et al. utilised Random Forest regression to forecast customer profitability in the insurance sector, demonstrating that preliminary clustering of customers based on behavioural attributes significantly enhances predictive accuracy by mitigating data heterogeneity. Their findings highlight the synergy between unsupervised and supervised learning in refining segmentation outcomes.⁶⁵⁶ Similarly, Lam proposed a two-stage approach combining gradient boosting and neural networks to predict customer profitability. While his model improved overall performance, it struggled to consistently identify the most valuable customers, suggesting that high-value segments may exhibit unique

⁶⁵² Verhoef, P. C., & Donkers, B. (2001). Predicting Customer Potential Value: An Application in the Insurance Industry. *Decision Support Systems*, 32(2), pp. 189-199.

⁶⁵³ Han et al. (2011), op. cit.

⁶⁵⁴ Xiahou, J., Xu, Y., Zhang, S., & Liao, W. (2016). Customer profitability analysis of automobile insurance market based on data mining. In: *2016 11th International Conference on Computer Science & Education (ICCSE)*, IEEE, pp. 603-609.

⁶⁵⁵ Verhoef & Donkers (2001), op. cit.

⁶⁵⁶ Fang, K., Jiang, Y., & Song, M. (2016). Customer profitability forecasting using Big Data analytics: A case study of the insurance industry. *Computers & Industrial Engineering*, 101, pp. 554-564.

characteristics requiring specialized techniques.⁶⁵⁷ Also, Abdul-Rahman et al. applied K-Modes clustering and Decision Tree classification to segment life insurance customers into three groups: “Potential High-Value Customers,” “Low-Value Customers,” and “Disinterested Customers.” The Decision Tree model using the Gini criterion with 10-fold cross-validation achieved 81.30% accuracy. These insights can help insurers optimise marketing strategies and tailor services to different customer segments.⁶⁵⁸

Recent studies have advanced the application of machine learning techniques in insurance customer segmentation, offering promising avenues for identifying high-value “golden” policyholders critical to the insurance industry. Jandaghi and Moradpour employed fuzzy clustering, specifically the fuzzy C-means algorithm, to segment life insurance customers based on demographic and policy profiles, distinguishing investment-focused and life-security-oriented policyholders. Their approach demonstrated how soft computing can uncover granular segments, providing a foundation for pinpointing high-value clients that align with the “golden” policyholder archetype, though it lacks a predictive layer for real-time classification.⁶⁵⁹ Complementing this, Jamotton et al. applied a suite of clustering techniques—including K-means with Burt distance, fuzzy K-means, and spectral clustering—to an auto insurance portfolio, achieving superior risk stratification and pricing accuracy compared to traditional methods like K-modes. Their findings emphasize the potential of hybrid clustering approaches to isolate profitable segments, offering a robust starting point for predictive models targeting golden policyholders. Together, these advancements underscore the synergy of unsupervised learning in refining segmentation, a critical step toward leveraging artificial intelligence to predict and prioritize high-value insurance customers effectively.⁶⁶⁰

Despite these contributions, gaps persist in the literature. Many studies focus on profitability as a segmentation criterion but overlook the predictive scalability needed for real-time applications in large-scale insurance operations.

⁶⁵⁷ Lam, S. (2018). The Ensemble of Neural Network and Gradient Boosting for the Prediction of Customer Profitability. *Model Assist. Stat. Appl.*, 13(4), pp. 329-340.

⁶⁵⁸ Abdul-Rahman, S., Arifin, N. F. K., Hanafiah, M., & Mutalib, S. (2021). Customer segmentation and profiling for life insurance using k-modes clustering and decision tree classifier. *International Journal of Advanced Computer Science and Applications*, 12(9), pp. 434-444.

⁶⁵⁹ Jandaghi, G., & Moradpour, Z. (2015). Segmentation of life insurance customers based on their profile using fuzzy clustering. *International Letters of Social and Humanistic Sciences*, 61, pp. 17-24.

⁶⁶⁰ Jamotton, C., Hainaut, D., & Hames, T. (2024). Insurance Analytics with Clustering Techniques. *Risks*, 12(9), 141.

Furthermore, the integration of Recency, Frequency, and Monetary (RFM) analysis—a proven framework in marketing analytics—with advanced classification techniques like Support Vector Machine (SVM) remains underexplored in the insurance context.⁶⁶¹ Building on this foundation, the present research proposes a hybrid methodology that combines k-means clustering with SVM classification to enhance customer segmentation accuracy. By leveraging RFM attributes to identify "golden" policyholders and employing SVM to predict cluster membership using demographic, vehicle, and policy-related features, this study offers a precise, automated, and scalable solution for insurers aiming to optimise marketing strategies and resource allocation.

2. DATA AND METHODOLOGY

Data Description

This study utilises a longitudinal dataset of CASCO insurance customers from one of Montenegro's largest insurers. The dataset includes 4,293 customers and their 14,541 policies recorded between 2014 and 2020. It encompasses customer demographics such as age, gender, and region, policy details including duration, insured vehicle type and brand, as well as purchasing behaviour. The latter includes monetary value, defined as the premium minus claims, policy recency, claim recency, policy frequency, and claim frequency. To quantify recency, policies are ranked into five groups, where the most recent 20% receive a score of five, while the oldest 20% receive a score of one. Claims are similarly ranked, but customers with no claims receive a score of zero. Ideally, a valuable customer should have a high recency score for policies and a low recency score for claims. The distribution and statistics of the variables for this data set are shown in Table 1.

The dataset distribution indicates that most insured individuals are middle-aged, with an average age of around 50 years. There is a notable predominance of male policyholders, and the majority come from the central region of the country. The average policy duration is approximately one year, while mid-range passenger vehicles make up the largest share of insured assets. In terms of purchasing behaviour, the average monetary value of a policy is slightly over 100 euros, while recency scores suggest that many policyholders do not demonstrate strong loyalty. The average number of policies per customer is six, with some customers filing as many as ten claims. The most profitable customer in the dataset generated approximately 30,000 euros, while the least profitable recorded a net loss of around 54,000 euros.

⁶⁶¹ Fader et al. (2005), op. cit.

Table 1. Distribution of variables and statistics

Variable Name	Min	Max	Avg	St Dev	Values
<u>Customer data</u>					
Age	19.00	88.00	49.22	12.66	
Gender					M (9333), F (5208)
Region					Central (8092), Southern (5318), Northern (841), unknown (178), Other_International (112)
<u>Policy data</u>					
Duration	3.00	731.00	355.86	33.23	
Vehicle_type					Passenger vehicle (14262), Cargo vehicle (117), SUV (116), Motorcycle (38), Special vehicles (8)
Brand					Middle (8628), Premium (3180), Budget (2733)
<u>Purchasing data</u>					
Monetary	-46657.1	3456.9	104.9	1151.1	
Recency_policies	1.00	5.00	3.00	1.41	
Recency_claim	0.00	6.00	0.54	1.36	
Frequency_policies	1.00	41.00	5.82	5.03	
Frequency_claim	0.00	10.00	0.88	1.25	

Source: Author's calculation

Hybrid Clustering-Classification Approach

The study employs a hybrid clustering-classification approach to predict the value of existing customers based on their purchasing history. The assumption is that customers will continue purchasing policies in the forecast period, which is reasonable in stable, non-contractual insurance markets.⁶⁶²

The methodology consists of two models: the first groups customers into homogeneous clusters based on purchasing behaviour, while the second predicts

⁶⁶² Verhoef & Donkers (2001), op. cit.

cluster membership for new customers based on demographic, vehicle, and policy-related features. This approach is particularly useful for large, unlabeled datasets where customer segmentation is not predefined. By applying clustering first, hidden customer patterns are uncovered, while classification enables automated predictions without the need to reapply clustering each time new data is processed. This not only streamlines the segmentation process but also enhances computational efficiency, making it highly applicable in large-scale CRM systems.⁶⁶³

For clustering, the study employs k-means to segment customers using an adapted RFM model.⁶⁶⁴ In addition to the standard recency, frequency, and monetary attributes, this adaptation incorporates insurance-specific variables, including the date of the last policy, the date of the last claim, the number of policies held, the number of claims made, and the net value of the policy. Given its proven effectiveness in previous RFM-based clustering studies, the k-means method was selected as the primary clustering technique.^{665 666 667}

Following clustering, an SVM classifier is trained to predict customer cluster membership based on demographic, policy, and vehicle-related characteristics. SVM is particularly well-suited for this task due to its strong generalisation capabilities and robustness against overfitting.^{668 669} To ensure optimal parameter selection, the model undergoes training using a combination of Grid Search and k-fold cross-validation. The dataset is split into a 70-30% training-test ratio, with

⁶⁶³ D’Haen, J., Van den Poel, D., & Thorleuchter, D. (2013). Predicting customer profitability during acquisition: Finding the optimal combination of data source and data mining technique. *Expert systems with applications*, 40(6), pp. 2007-2012.

⁶⁶⁴ MacQueen, J. (1967). Some methods for classification and analysis of multivariate observations. In: *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, Vol. 5, University of California Press, pp. 281-298.

⁶⁶⁵ Hosseini, S. M. S., Maleki, A., & Gholamian, M. R. (2010). Cluster analysis using data mining approach to develop CRM methodology to assess the customer loyalty. *Expert Systems with Applications*, 37(7), pp. 5259-5264.

⁶⁶⁶ Rogić, S., & Kaščelan, L. (2019). Customer value prediction in direct marketing using hybrid support vector machine rule extraction method. In: *New Trends in Databases and Information Systems*, Springer International Publishing, pp. 283-294.

⁶⁶⁷ Djurišić, V., Kaščelan, L., Rogić, S., & Melović, B. (2020). Bank CRM optimization using predictive classification based on the support vector machine method. *Applied Artificial Intelligence*, 34(12), pp. 941-955.

⁶⁶⁸ Kaščelan, L., & Vuković, S. (2024). Addressing class imbalance in customer response modeling using random and clustering-based undersampling and SVM. *IPSI Transactions on Internet Research*, 20(2), pp. 74-82.

⁶⁶⁹ Djurišić et al. (2020), op. cit.

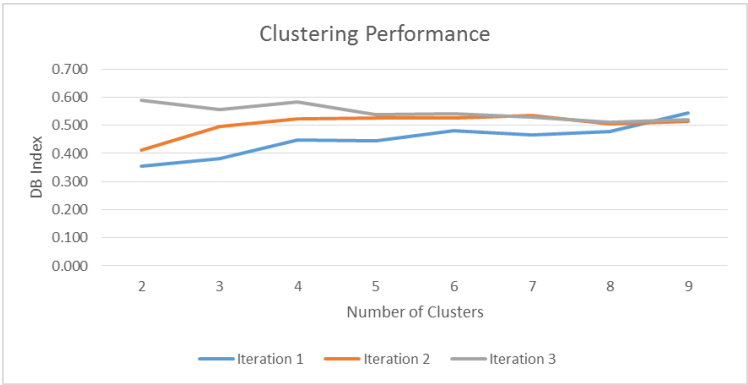
k-fold cross-validation applied to improve model generalisation. Performance evaluation is conducted using overall accuracy, class recall, and class precision, ensuring a comprehensive assessment of predictive capability.

This methodology enables insurers to efficiently identify high-value customers, optimise direct marketing efforts, and enhance customer relationship management strategies. By integrating clustering and classification, the approach provides a scalable and automated solution for predicting customer value, ultimately improving decision-making in the insurance sector.^{670 671}

3. RESULTS

The analysis began with k-means clustering of customers based on RFM variables, conducted over three iterations. In each iteration, we tested values of k ranging from 2 to 9 to determine the optimal number of clusters (Figure 1). The first iteration, guided by the minimum Davies-Bouldin (DB) index of 0.355, yielded two clusters. The larger of these was re-clustered in the second iteration, again producing two clusters with a minimum DB index of 0.412. In the third iteration, the larger cluster from the second step was further segmented, resulting in eight clusters (minimum DB index of 0.510). This process ultimately generated ten distinct clusters, including two retained from prior iterations, as detailed in Table 2.

Figure 1. Determining the optimal number of clusters based on the minimum value of the DB index



Source: Author’s calculation

⁶⁷⁰ Ferraretti, D., Gamberoni, G., & Lamma, E. (2012). Unsupervised and supervised learning in cascade for petroleum geology. *Expert Systems with Applications*, 39(10), pp. 9504-9514.

⁶⁷¹ Rogić & Kaščelan (2019), op. cit.

Table 2. Centroid cluster model for customer segmentation by RFM variables

Variables	CI0	CI1	CI2	CI3	CI4	CI5	CI6	CI7	CI8	CI9
Monetary	87.35	1920.92	-1691.26	1055.58	589.54	290.46	-871.30	-268.58	-4523.67	-23225.26
Recency_policies	2.86	3.40	2.80	3.34	3.34	3.06	2.95	2.76	2.44	2.00
Recency_claim	0.61	0.20	1.61	0.24	0.21	0.26	1.43	1.32	2.04	2.17
Frequency_policies	6.43	3.65	4.25	6.66	4.89	5.69	6.30	5.63	2.32	1.22
Frequency_claim	1.10	0.20	1.53	0.70	0.41	0.44	2.04	2.00	1.39	1.00
Items	5028	98	191	667	1896	4814	439	1196	194	17

Source: Author's calculation

Examining the cluster centroids reveals clear distinctions. Cluster 1 (Cl1), comprising 98 policyholders, emerges as the "Golden" segment, characterised by high-value, recent policies, minimal and dated claims, averaging four policies per customer, and a low claim frequency. Cluster 3 (Cl3), with 667 "Silver" customers, follows, boasting an average policy value of €1,055 and over six policies per customer. Cluster 4 (Cl4), labelled "Bronze," includes 1,896 policyholders with an average contribution of €589. Clusters 5 (Cl5) and 0 (Cl0) represent "Standard Higher" (€290 average) and "Standard Lower" (€87 average) segments, respectively.

On the riskier end, Cluster 7 (Cl7) ("Less Risky") shows a negative monetary value due to slightly higher claims than premiums, while Cluster 6 (Cl6) ("Medium Risky") reflects greater losses. Cluster 2 (Cl2) ("Risky") features significant claims despite fewer policies, and Cluster 8 (Cl8) ("High-Risk") exhibits substantial losses with limited policies. Finally, Cluster 9 (Cl9) ("Very High-Risk"), with just 17 members, averages a single policy and a staggering €23,000 loss. Clusters primarily differ in monetary value, policy count, and claim frequency, with recency metrics showing subtler variation, slightly elevated in the riskiest groups.

Next, the dataset was split into a training set (10,172 items) and a test set (4,369 items) using stratified sampling to maintain cluster distribution parity. With clusters as class labels and predictors from Table 1, an SVM classifier (Model 2) was trained, optimising parameters to $C = 10,000$ and $\gamma = 1.0E-10$ via Grid Search and 10-fold cross-validation.

Performance, assessed through accuracy, recall, and precision (Table 3), demonstrates exceptional results. The model achieved over 99% overall accuracy on the test set, with class recall exceeding 80% and precision surpassing 98% across all clusters. For the "Golden" cluster (Cl1), 96% of high-value customers were correctly identified, with no false positives (100% precision). "Silver" (Cl3) and "Bronze" (Cl4) clusters saw misclassification rates below 2%, affirming the model's precision in targeting valuable segments.

Risky clusters were equally well-handled: no "High-Risk" (Cl8) customers were misclassified, and while 20% of "Very High-Risk" (Cl9) were misplaced, no others were falsely labelled as such. Comparable cross-validation and test-set accuracies underscore the SVM's robust generalisation, aligning with prior literature.

Table 3. Predictive model performance for customer classification

Cluster	Training set (10-fold cross-validation)	Test set (unknown data)		
	Class Recall	Class Precision	Class Recall	Class Precision
CI0	99.83%	99.32%	99.87%	99.21%
CI1	91.30%	100.00%	96.55%	100.00%
CI2	97.76%	98.50%	98.25%	98.25%
CI3	98.29%	98.71%	98.00%	99.49%
CI4	96.68%	99.38%	98.59%	99.29%
CI5	99.73%	98.56%	99.86%	99.31%
CI6	99.02%	99.02%	99.24%	99.24%
CI7	98.09%	99.64%	97.21%	100.00%
CI8	99.26%	98.54%	100.00%	98.31%
CI9	92.31%	100.00%	80.00%	100.00%
Overall Accuracy	99.05% +/- 0.44%		99.31%	

Source: Author's calculation

Table 4 confirms consistent profitability distributions between training and test sets, indicating the SVM classifier's success in aligning unknown customers with appropriate clusters based on purchasing behaviour similarities.

Table 4. Cluster distribution in the training and test sets and customer profitability by clusters

Cluster Name	Items	Min Prof	Max Prof	Avg Prof
Training set				
Gold	69	1492.94	20550.95	6562.56
Silver	467	822.97	29203.60	6828.39
Bronze	1327	440.13	14090.18	2912.91
Standard Higher	3369	190.90	16675.93	1635.95
Standard Lower	3513	-2467.27	2685.16	534.89
Less Risky	837	-8587.91	-61.23	-1609.90
Medium Risky	307	-22913.91	-581.33	-5782.35
Risky	134	-15538.43	-1313.54	-7292.16
High-Risk	136	-53950.08	-2242.94	-11351.36
Very High-Risk	13	-40437.81	-14233.16	-26994.62

Test set				
Gold	28	1227.60	21550.95	8503.10
Silver	197	472.69	29203.60	6554.95
Bronze	565	446.41	29203.60	2940.58
Standard Higher	1453	190.05	16675.93	1698.01
Standard Lower	1525	-2467.27	2685.16	509.42
Less Risky	349	-8587.91	-101.81	-1505.05
Medium Risky	132	-22913.91	-580.01	-5088.37
Risky	57	-14238.43	-1417.11	-6559.33
High-Risk	59	-49094.57	-2242.94	-9748.26
Very High-Risk	4	-46657.14	-19162.92	-29552.75

Source: Author's calculation

4. DISCUSSION

This hybrid approach delivers outstanding predictive accuracy, effectively identifying high-value and risky policyholders alike. Its precision in classifying "Golden," "Silver," and "Bronze" customers, alongside reliable risk segmentation, positions it as a powerful tool for enhancing insurance CRM strategies. These results carry significant implications for insurance companies seeking to refine their operational and strategic decisions in a competitive market.

For insurers, the ability to pinpoint "Golden" policyholders—those who generate substantial revenue with minimal claims—enables a more focused allocation of resources. Marketing efforts can be tailored to retain these high-value clients through personalised offers, loyalty incentives, or premium services, thereby maximising long-term profitability. Similarly, the accurate identification of "Silver" and "Bronze" segments allows for tiered engagement strategies. For instance, "Silver" customers, with their solid contributions and higher policy frequency, might be targeted for upselling opportunities, such as bundling additional coverage, while "Bronze" policyholders could be nurtured to increase their engagement and transition into higher-value tiers over time. This granular segmentation moves beyond traditional, broad-stroke approaches, offering a data-driven pathway to optimise customer lifetime value.

Equally critical is the model's capacity to flag risky segments—particularly "High-Risk" and "Very High-Risk" clusters, where substantial losses outweigh premiums. By identifying these policyholders with high precision, insurers can proactively adjust pricing strategies, impose stricter underwriting criteria, or even limit exposure to such customers. For example, the "Very High-Risk" cluster,

despite its small size, represents a disproportionate financial drain (averaging €23,000 in losses per customer). Armed with this insight, companies can make informed decisions to either mitigate risk through higher premiums or strategically phase out such policyholders, thereby safeguarding overall portfolio health. The "Less Risky" and "Medium Risky" clusters, with more moderate losses, might instead prompt targeted interventions, such as offering risk management advice or telematics-based discounts to encourage safer behaviour, balancing retention with profitability.

Operationally, the scalability and automation of this RFM-SVM framework streamline decision-making across large customer bases. Unlike manual or heuristic methods, which falter with growing datasets, this AI-driven solution integrates seamlessly into CRM systems, enabling real-time classification of new policyholders without repeated clustering. This efficiency not only reduces administrative overhead but also empowers insurers to respond swiftly to market shifts or emerging customer trends. For instance, during renewal seasons, the model can prioritise outreach to "Golden" and "Silver" clients while simultaneously flagging "Risky" renewals for review, optimising both retention and risk management in a single workflow.

Strategically, these findings position insurance companies to sharpen their competitive edge. By aligning marketing budgets with customer value—concentrating resources on high-return segments while minimizing losses from high-risk ones—insurers can enhance return on investment. Furthermore, the predictive accuracy (over 99% on the test set) instils confidence in data-driven planning, from pricing adjustments to product development. For example, insights into the "Bronze" cluster's moderate value might inspire new, cost-effective policy offerings tailored to this group's needs, expanding market share without compromising margins.

In essence, this methodology transforms raw data into actionable intelligence, bridging the gap between customer behaviour and business outcomes. It empowers insurers to not only identify who drives profit and who poses risk but also to act decisively, whether by nurturing loyalty among top-tier clients, mitigating losses from problematic segments, or innovating to capture untapped potential. As competition intensifies and customer expectations evolve, adopting such a precise, scalable tool could redefine how insurance firms manage relationships and allocate resources, ultimately strengthening their resilience and profitability in a dynamic industry landscape.

* * *

This study introduced a robust, AI-driven methodology for predicting high-value insurance policyholders by integrating k-means clustering with Support Vector Machine (SVM) classification. Leveraging Recency, Frequency, and Monetary (RFM) attributes, the approach first segmented customers into ten distinct clusters, ranging from the highly profitable "Golden" policyholders to the loss-heavy "Very High-Risk" group, using a real-world dataset of 4,293 CASCO insurance customers from Montenegro spanning 2014 to 2020. Subsequently, an SVM classifier, trained on demographic, vehicle, and policy-related features, achieved exceptional predictive accuracy, exceeding 99% on the test set, enabling reliable identification of cluster membership for new policyholders. This hybrid framework not only uncovered hidden patterns in customer behaviour but also delivered a scalable, automated solution for customer segmentation, surpassing the limitations of traditional manual or heuristic approaches.

The implications of these findings are profound for insurance companies. By accurately identifying "Golden," "Silver," and "Bronze" policyholders, insurers can optimise marketing strategies, enhance retention efforts, and maximise profitability through targeted resource allocation. Simultaneously, the precise classification of risky segments empowers firms to mitigate financial exposure through adjusted pricing, stricter underwriting, or strategic customer management. Operationally, the methodology's efficiency and adaptability make it a practical tool for large-scale CRM systems, facilitating real-time decision-making in dynamic market conditions. Collectively, these capabilities underscore the transformative potential of combining RFM-based clustering with SVM classification, offering actionable insights that bridge customer value and business outcomes.

While this study demonstrates significant advancements in predictive analytics for insurance, opportunities for further refinement remain. Future research could explore alternative clustering techniques, such as fuzzy C-means or spectral clustering, to enhance segmentation granularity or incorporate additional features, like telematics data or macroeconomic indicators, to enrich predictive models. Extending the approach to other insurance domains, such as life or health insurance, could also broaden its applicability. Nevertheless, the current findings establish a compelling foundation for insurers aiming to leverage artificial intelligence to refine customer relationship management, improve operational efficiency, and secure a competitive edge in an increasingly data-driven industry.

THE IMPORTANCE OF MARKETING WEB METRICS FOR MODERNISATION OF THE INSURANCE MARKET

In today's digital age, the insurance market is facing major changes under the influence of new technologies and changing consumer needs. One of the key factors in the modernisation of this market is the application of marketing web metrics, which enables precise monitoring and analysis of user behaviour on the Internet. These metrics provide insights into the efficiency of marketing strategies, identifying potential customer preferences, and optimising offers and communications. By implementing advanced data analysis tools, insurance companies can improve their business processes, target specific market segments and compete efficiently in a dynamic business environment. This paper investigates the importance of marketing web metrics as a key tool for the modernization of the insurance market, with a special focus on its application in creating competitive advantages and increasing client satisfaction.

1. DIGITAL MARKETING AND ITS SIGNIFICANCE

The fourth industrial revolution, which led to a significant improvement in digital technology and the spread of the Internet, caused radical changes in the way companies meet the demands of their consumers⁶⁷², as well as in corporate communication⁶⁷³. A special type of marketing that uses digital channels such as computers, text or multimedia messages via mobile phones, interactive television, IPTV, various forms of digital displays, etc. for the promotion of products and services, as well as for establishing and maintaining relations with consumers is digital marketing.

In the process of applying digital marketing, a company can use websites, search engines, blogs, social media, video, email and similar channels to reach customers. The main purpose of digital marketing is for the company to get closer to consumers using digital media to better research and understand them, add

⁶⁷² Rancati, E. (2010). Market-driven management, global markets and competitive convergence. *Symphonya - Emerging Issues in Management*, 1, pp. 76-85.

⁶⁷³ Winer, R. S. (2009). New communications approaches in marketing: Issues and research directions. *Journal of Interactive Marketing*, 23, pp. 108-117.

value to products, expand distribution channels and increase sales through digital promotion.⁶⁷⁴

One of the most important novelties in the digital approach to marketing, compared to the classical approach, is that the clear boundary between the roles of service providers and service recipients: final or business customers is erased. In digital marketing, the boundaries between these roles are blurred, and more complex relationships are created between participants. Namely, there is a sharing of free marketing content that attracts potential consumers and thus increases their engagement and the power of companies to impose themselves as relevant and capable of instilling trust in existing and potential customers⁶⁷⁵. To understand the importance of digital marketing in the future, it is important to consider the key aspects of a company's interactions with consumers, which it must understand in order to manage them efficiently.

Digital marketing today encompasses a much broader field than it used to, including the variety of devices people use, such as smartphones, computers, and other connected devices. Also important is the Internet of Things (IoT), which enables devices to communicate and exchange data without human intervention. Interactions often take place through digital platforms such as social networks and search engines, while various forms of digital media are used to engage audiences. The collection of user data has become crucial, and in order to do so legally, the relevant regulations must be followed. Finally, digital technology, such as marketing platforms and tools for creating interactive experiences, plays a significant role in today's marketing.⁶⁷⁶

Unlike traditional marketing, which is static and often referred to as „one-way“ communication, digital marketing is dynamic and allows interaction. Namely, clients cannot communicate with bidders through billboards or printed ads, while digital marketing provides a way for two-way communication between companies and their real or potential customers and other stakeholders, as well as communication between customers themselves.

In the modern age, a large number of people spend a lot of time on the Internet. Thanks to digital marketing, this reality is used, and products and services are

⁶⁷⁴ Filipović, J. (2021). *Digitalni marketing*. Belgrade: University of Belgrade, Faculty of Economics and Business, p. 14.

⁶⁷⁵ Kucuk, S. U., & Krishnamurthy, S. (2007). An analysis of consumer power on the Internet. *Technovation*, 27, pp. 47-56.

⁶⁷⁶ Craffey, D., & Ellis-Chadwick, F. (2019). *Digital marketing*. Pearson Education Limited, p. 5.

promoted online. In this way, companies' marketing efforts increase the likelihood of reaching customers by targeting them where they spend most of time. A successful digital marketing strategy generally involves a combination of different methods, such as online advertising, search engine optimisation, marketing, social media content management and creation, and others.

From startup to enterprise, a multifaceted approach to digital marketing can lead to digital marketing goals and significant commercial benefits: online sales growth, branding, content creation, personalization, considerable cost savings, entry into new, remote markets, and better measurement of marketing results in real time.⁶⁷⁷

2. THE INFLUENCE OF THE INTERNET ON THE EFFICIENCY OF MARKETING

The impact of the Internet on marketing efficiency has become the subject of numerous researches and studies, as the digital revolution has changed the way companies do business and communicate with consumers. The Internet enables faster, more accurate and cheaper marketing activities, which makes marketing more effective. In order to analyse the impact of the Internet on the efficiency of marketing, the starting point is the improvement of technology and tools that were necessary for e-commerce.

Advances in tools and technology make it possible to review and analyze the large amount of data needed to provide a true picture of a company's marketing performance. Having the right tools and technology in your company is a necessary condition for managing marketing efficiency. Without basic tools and technology, it's very difficult for marketers to consider anything but the simplest metrics in an effort to leverage analytics to improve their results.

With the tool, marketers can build and manage a sustainable analytics process, which is broad enough to allow consideration of the large amount of data necessary to provide a true picture of marketing performance. That's why having advanced tools and technology is essential to create and manage an effective marketing analytics process that contributes to marketing efficiency. The fourth industrial revolution, which brought significant advances in digital technologies and the spread of the Internet, caused major changes in the way companies meet the needs of their consumers and in corporate communication. One of the key

⁶⁷⁷ Ahuja, V. (2016). *Digital marketing*. Oxford: Oxford University Press, pp. 14-16.

innovations in digital marketing is the free sharing of content that attracts potential customers, which helps build trust with existing and new customers.⁶⁷⁸

The Internet has significantly improved the efficiency of marketing through the development of technologies and tools that enable the analysis of large amounts of data. Companies now use advanced tools to build databases and analyze marketing performance. These tools allow marketers to effectively manage marketing analytics processes, which is essential for successful marketing.

Technology refers to the underlying platforms that enable marketing processes, while tools are specific software systems that perform certain functions, such as, above all, performance monitoring through dashboards. Although these terms are often used together, the distinction between them is becoming less pronounced as technology advances and integrates new features.

As previously stated, there are two types of marketing today: traditional and digital marketing. Traditional marketing refers to methods that have been used for decades, such as television commercials, print ads, billboards, and radio spots. These methods usually target a wider audience, in a specific geographic area or in a specific demographic group.⁶⁷⁹ On the other hand, digital marketing uses digital technologies such as social media, email marketing, search engine optimisation (SEO) and online advertising, which allow more precise targeting of the audience based on their interests, behaviour or geographic location.⁶⁸⁰ Although traditional marketing can still be effective, digital marketing has become increasingly popular and important due to the development of technology and the Internet.⁶⁸¹

Digital marketing enables businesses to reach a wider audience, measure marketing efforts and adjust their strategies based on analysed data. Also, digital marketing can be more profitable and bring a higher ROI (Return on Investment) compared to traditional marketing.⁶⁸² In addition, social media is crucial to marketing strategies, as there is a strong correlation between customers' use of

⁶⁷⁸ Craffey & Ellis-Chadwick (2019), op. cit., p. 5.

⁶⁷⁹ Rosario, A. M. F. T., & Cruz, R. N. (2019). Determinants of Innovation in Digital Marketing. *Journal of Reviews on Global Economics*, 8(1), pp. 1722-1731.

⁶⁸⁰ Montgomery, K. C., Chester, J., Grier, S. A., & Dorfman, L. (2012). The New Threat of Digital Marketing. *Pediatric Clinics*, 59, pp. 659-675.

⁶⁸¹ WSI (2013). *Digital Minds: 12 Things Every Business Needs to Know about Digital Marketing*. Altona, MB, Canada: Friesen Press, p. 7.

⁶⁸² Bala, M., & Verma, D. (2018). A Critical Review of Digital Marketing. *International Journal of Management, IT & Engineering*, 8(10), pp. 321-339.

social media and their brand loyalty. Greater use of social media leads to greater loyalty, which in turn improves sales performance. However, many organizations are not ready to invest in digital marketing because they still see it as an addition to traditional methods.⁶⁸³

Digital marketing is one of the most important drivers of innovation that enables the competitiveness and growth of companies. Innovation is defined as the process of introducing new ideas, products or methods to improve an existing system or create a new one. This process involves creativity and problem-solving to develop solutions that meet the changes in society. Marketing innovations refer to the introduction of new methods of promoting, evaluating or selling products/services, as well as to significant changes in product design or packaging. As consumers increasingly use digital channels to research and shop, businesses must embrace digital marketing to remain competitive. It is very important for companies to have an effective marketing system that provides consumers with a wide range of alternatives, including new product launches, promotions and increasing loyalty, in order to attract and retain customers.

Innovation positively affects business performance, increasing customer satisfaction, production speed, growth and efficiency. Research on the example of Fortune 1000 companies indicates an increase in sales, internal efficiency and a reduction in production costs.⁶⁸⁴ Empirical studies of marketing innovations also show a positive impact on performance, including growth in sales, profits, cash flow, and shareholder value. For example, a study of the top 100 Korean firms found that investing in social media can lead to high financial performance.⁶⁸⁵ Marketing innovations enable companies to achieve competitive advantages in the market, improving economic efficiency, product differentiation and increasing consumption.

Digital marketing has become crucial for many companies, as it allows automating processes, measuring performance and improving marketing strategies. In the past, the digitalization of marketing was the privilege of large

⁶⁸³ Pollák, F., & Markovič, P. (2021). Size of business unit as a factor influencing adoption of digital marketing: Empirical analysis of SMEs operating in the central European market. *Administrative Sciences*, 11(3), 71, <https://doi.org/10.3390/admsci11030071>

⁶⁸⁴ Cho, H. J., & Pucik, V. (2005). Relationship between Innovativeness, Quality, Growth, Profitability, and Market Value. *Strategic Management Journal*, 26(6), pp. 555-575.

⁶⁸⁵ Chung, S., Animesh, A., Han, K., & Pinsonneault, A. (2014). Firm's social media efforts, consumer behavior, and firm performance. *ICIS 2014 Proceedings*, 14, pp. 1-20.

companies, but today it is also available to smaller companies. Digital marketing enables the collection and analysis of data on the presence of customers on the Internet, which helps in optimising marketing activities and recognising moments when specific content should be applied or special offers activated.

The implementation of modern digital marketing enables companies to improve customer service, focus on the customer and thus achieve high financial performance.⁶⁸⁶ Modern digital marketing 5D includes digital devices, Internet of Things, digital platforms, digital media, digital data and digital technologies. Audiences interact with companies using a variety of digital devices, such as smartphones, tablets, computers, televisions, gaming devices, virtual assistants and other devices. The Internet of Things is a system of devices and objects that can transmit data over a network without human intervention, using machine-to-machine interactions.⁶⁸⁷ Interactions often take place through digital platforms such as Facebook, Google, YouTube, X (ex Twitter), LinkedIn, Amazon and others. To win and engage users, digital media such as ads, email messages, search engines and social networks are used. Thanks to digital marketing, companies collect data on the profiles of their users, and the protection of that data is regulated by legislation in most countries.

Companies use marketing technologies (martech) to create interactive and personalised experiences, enabling better user engagement and more effective communication with them. These technologies include content management tools, analytics and automation, and are implemented through websites, mobile apps, email campaigns and other digital channels.

Thanks to 5D digital marketing, consumers now have a greater choice of products and services than ever, and companies have the opportunity to expand their market and communicate with audiences in new ways. By embracing new technologies, a company can increase brand awareness, increase sales, and improve customer experience. Effective innovations in digital marketing can contribute to better attracting and retaining customers, i.e. strengthening loyalty, resulting in increased sales and overall company performance.⁶⁸⁸ These

⁶⁸⁶ Dumitriu, D., Militaru, G., Deselnicu, D. C., Niculescu, A., & Popescu, M. A. M. (2019). A perspective over modern SMEs: Managing brand equity, growth and sustainability through digital marketing tools and techniques. *Sustainability*, 11(7), 2111, <https://doi.org/10.3390/su11072111>

⁶⁸⁷ Craffey & Ellis-Chadwick (2019), op. cit., p. 5.

⁶⁸⁸ Javalgi, R. R. G., Radulovich, L. P., Pendleton, G., & Scherer, R. F. (2005). Sustainable Competitive Advantage of Internet Firms: A Strategic Framework and Implications for Global Marketers. *International Marketing Review*, 22(6), pp. 658-672.

capabilities enable SMEs to compete with large players in the market. Digital marketing innovations have the potential to positively impact business performance by enabling companies to reach a wider audience, improve customer engagement and gather valuable data for targeted advertising.⁶⁸⁹

Innovations in digital marketing have become more popular and important in recent years due to the increasing reliance on digital channels to communicate with consumers. With the widespread adoption of digital technologies, an increasing number of people are present on social networks. Companies should adapt to this change in the behaviour of potential and existing consumers by embracing innovations in digital marketing. These innovations offer companies new opportunities to engage with their target consumers, collect valuable data, and survive or emerge ahead of the competition. As a result, many companies are investing in digitization and introducing marketing innovations in order to be relevant and competitive in the digital market.⁶⁹⁰

In the following, the key factors of the impact of the Internet on marketing effectiveness are discussed, such as global availability and scale, personalization and market segmentation, cost reduction, increased interactivity and user engagement, as well as the use of artificial intelligence and automation.

Global availability and range increase the chances of sales growth and brand recognition. One of the Internet's most significant impacts on marketing is its ability to connect businesses to the global marketplace. Through the Internet, companies can reach consumers all over the world, thereby significantly expanding the market and reducing the geographical barriers that existed before the digital era. As a result, marketing becomes more efficient as market reach is greater and distribution costs are reduced.⁶⁹¹

The Internet enables companies to personalise and segment the market, that is, to collect data about users and develop personalised marketing campaigns based on that data. By using analytics and user behaviour data, businesses can create targeted ads and offers that match specific consumer needs and wants. This approach to personalised marketing is much more effective than traditional

⁶⁸⁹ Ibid.

⁶⁹⁰ Peter, M. K., & Dalla Vecchia, M. (2021). The Digital Marketing Toolkit: A Literature Review for the Identification of Digital Marketing Channels and Platforms. In: *New Trends in Business Information Systems and Technology. Studies in Systems, Decision and Control*, Vol. 294, Dornberger, R. (ed.), Springer, pp. 251-265.

⁶⁹¹ Kotler, P., Kartajaya, H., & Setiawan, I. (2017). *Marketing 4.0: Moving from Traditional to Digital*. Wiley, pp. 47-53.

approaches, as it increases the likelihood that consumers will respond positively to marketing activities.

One of the main reasons why the Internet has improved the effectiveness of marketing is the reduction of costs compared to traditional forms of advertising, such as TV commercials, radio and print materials. Digital marketing offers much cheaper options for advertising and promotion, including social media, SEO, email marketing and PPC (pay-per-click) campaigns. In addition to lower costs, digital channels allow companies to effectively track ROI (return on investment) and optimize their marketing strategies in real time.⁶⁹²

The Internet enables two-way communication between businesses and consumers, which has significantly increased user engagement. Through social networks, blogs, forums and other interactive platforms, businesses can communicate directly with consumers, respond to their comments and questions, and adjust marketing strategies based on feedback. This level of interactivity improves the effectiveness of marketing because it enables a faster and more relevant adaptation of the offer to the needs of the user .

The use of artificial intelligence (Artificial Intelligence - AI) and automation in marketing has become a key factor in increasing efficiency. Digital platforms use algorithms to personalise content, optimise ads, predict consumer behaviour, and automate marketing processes. For example, chatbots can provide 24/7 customer support, while automated email campaigns can target users with relevant content at the right time, increasing the chances of conversion.⁶⁹³

The Internet has significantly improved the effectiveness of marketing through global accessibility, personalization, cost reduction, interactivity and the use of new technologies such as artificial intelligence and automation. These factors allow businesses to more effectively reach their target audience, better understand their needs and quickly adapt their marketing strategies, thereby achieving a higher return on marketing investment.

3. WEB METRICS

Today, every 60 seconds on the Internet, 241 million emails are sent, 41.6 million WhatsApp messages are sent, 6.3 million Google searches are performed, 25.1 million hours are spent online (globally), 694,000 Instagram DMs are sent,

⁶⁹² Kotler et al. (2017), op. cit.

⁶⁹³ Craffey & Ellis-Chadwick (2019), op. cit.

360,000 tweets are sent on X (Twitter), 4 million Facebook posts are made, and 6,060 LinkedIn bios are submitted.⁶⁹⁴ The modern information age enables us today, more than ever before, to get a lot of data about consumers (clients), partners, competition and events in the environment. This data is unstructured and is growing three times faster than structured data, and it is predicted that in 2025 it will be the majority of data (90%) and amount to 175 billion terabytes.⁶⁹⁵ How we access and process these large amounts of data is crucial. It is for this reason that a set of procedures and tools called web analytics and consequently web metrics was developed.

Web analytics is the measurement, collection, analysis, and reporting of Internet data for the purpose of understanding and optimising Web usage. The purpose is to understand consumer behaviour online, measure their responses to digital marketing efforts, and optimise digital marketing elements and processes that drive customers to appropriate behaviour that benefits the business.⁶⁹⁶ In general, web analytics can be divided into descriptive (what happened), diagnostic (why it happened), predictive (what will happen) and prescriptive (how to influence it to happen). Predictive analytics, which makes it possible to predict future purchase decisions based on user behaviour, is of great importance. This type of analytics represents the next step in the development of marketing automation and allows organizations to use data to make informed decisions about future campaigns.

The basic steps in the web analytics process are: collecting data, processing data into metrics (data is turned into information), developing key performance indicators (KPIs) (measurable values that show how effectively a company achieves its goals) and formulating an online marketing strategy. As metrics represent a measurement system that quantifies trends, dynamics and characteristics of a phenomenon, marketing metrics are a set of benchmarks that help companies quantify, compare, and interpret their performance.⁶⁹⁷

Web metrics allow a company to measure the impact of online marketing activities on the company's profits and assets, better diagnose and make decisions

⁶⁹⁴ Kumar, N. (2024). Big Data Statistics 2025: Growth and Market Data, *Demandsage*, November 13, 2024, <https://www.demandsage.com/big-data-statistics> (accessed 10.4.2025)

⁶⁹⁵ Ibid.

⁶⁹⁶ Jarvinen, J., & Karjaluo, H. (2015). The use of Web analytics for digital marketing performance measurement. *Industrial Marketing Management*, 50, pp. 117-127.

⁶⁹⁷ Kotler, P., Keller, K. L., & Chernev, A. (2022). *Marketing Management*. Hoboken, NY: Pearson, p. 112.

about the amount, type and structure of marketing expenses. Web metrics data is essential for tailoring an insurance company's online marketing strategy and offering to profitable customers. Marketing and web metrics track and measure the factors that drive an insurance company's financial results. At the same time, they serve as a justification for marketing costs and investments. The main goal is to reduce costs and increase their efficiency.

There are a number of web metrics that can be used in digital marketing. Most authors divide them according to the stages of the consumer or client consumption process:

- brand awareness - these indicators explain the company's current and potential audience;
- engagement – these metrics show how the audience interacts with the company's digital content, e.g. banner, application, etc.;
- conversion – these metrics show the effectiveness of the company's efforts on certain digital channels and
- consumer loyalty - these metrics reflect what active customers feel and think about the company's brand.

The specific metrics of each of these categories will vary by type of digital tool, and we will encounter some of them in each of them. The most commonly used metrics for website performance is the Google Analytics toolkit, which includes: number of sessions, number of users, number of page views, number of pages per session, average session duration, bounce rate, new user rate and repeat visitor rate. The basic metrics related to email are: delivery rate, open rate, response rate, conversion rate and unsubscribe rate. Indicators used to measure the effectiveness of ads on the search engine are: views (impressions), click-through rate or number of clicks per view, conversion rate.

Social media metrics are related to brand awareness: awareness, audience growth rate, post reach, potential reach and social share of resonance; Engagement metrics are: applause rate average engagement rate, boost rate, viral rate, conversion metrics: conversion rate, click-through rate, bounce rate, cost per click, cost per thousand impressions, conversion rate; Customer metrics: Customer Testimonials, Customer Satisfaction Score and Promoter Net Score.

Mobile marketing metrics are on the rise today. Engagement indicators are: session duration, session interval, interaction flow, interaction rate, opt-in, opt-out, stickiness indicators, and retention rate. Conversion metrics are average cost per install, average cost per signup, cost per acquisition, average order value, and average revenue per user. Relationship indicators are: love relationship and app store ranking.

It is important for a company to understand what it can measure and what metrics are available. Depending on the goals, the company will decide which metrics will be used and which will be key for them to evaluate the success of the business.

A marketing automation system has become an integral part of marketing analytics as it collects data on interactions with potential customers. This data allows marketers to better understand purchase flows and identify areas for improvement. Through integration with CRM systems, digital marketing provides a broader perspective on customer interactions and enables better insights into the entire sales process.

For digital marketing, the HubSpot platform is very important, allowing accurate tracking and analysis of marketing metrics, including site visits, page performance, blogs, social media metrics, and CTA (call to action) clicks. This tool centralises all marketing efforts, enabling effective analysis and optimisation of marketing strategies. Through deep data analysis, the platform enables the recognition of successful and unsuccessful tactics, making the marketing process driven and results-oriented.

Using data such as conversion rates, click-through rates and SEO (Search Engine Optimization) metrics allows for the recognition of patterns in user behaviour and the optimisation of marketing campaigns. HubSpot, as an integrated marketing automation platform, helps analyze that data and guides marketers through the analytics process.

Marketing teams can use the above analytics tools for strategic and operational purposes. Strategic marketing analytics helps make decisions that direct resources in the most profitable way, while operational analytics focuses on optimising current marketing activities and testing the performance of campaigns.

It is important that marketers choose the right analytics tools according to the specific needs of their organizations. There are many tools available that can be used for different aspects of marketing analytics, and the selection depends on the types of metrics being tracked. This wide range of tools allows marketers to explore the best options for their specific goals.

Analytics tools in the field of operations and logistics are today closely linked to the digital presence of organizations, which goes beyond the boundaries of a simple website. This includes all digital touchpoints, including micro-sites, social networks, search engine optimization (SEO), search engine marketing (SEM) and

mobile applications. Marketers need tools that provide a holistic view of all these activities and their mutual impact on organisational performance.

More and more customers are researching sellers online, which means a website is critical to an organisation's digital marketing. If a website is not optimised or does not offer quick and easy access to information, it can be a problem for the company. That's why tools are needed that allow insight into the behaviour of site visitors in real time.

Google Analytics is the dominant tool in the field of marketing analytics. This free tool is used by many websites and provides valuable information about site visitors, traffic and content. Google Analytics provides insight into the number of visitors, demographic data, traffic sources, and keywords that bring users to the site. This tool is indispensable for site optimization, as it provides data that helps improve SEO features.

Google Analytics is constantly evolving and now offers the ability to track users across multiple devices, allowing data to be collected from a wide range of devices. However, in addition to Google Analytics, there are other analytical tools that can provide additional information and help in understanding the market. TrustRadius, for example, offers detailed analyses and rankings of analytics software based on user ratings, which can be useful for organisations looking to select the right tools for their specific needs.

In addition to the website, today it is important to analyze the company's presence on social networks and mobile platforms. To successfully manage a digital presence, marketers use tools that allow monitoring of brand conversations on social networks, as well as user engagement. Tools like HootSuite, Netbase, and SproutSocial make it possible to spot important interactions, such as customer complaints or brand sentiment analysis. Also, the mobile channel is crucial for many companies, as it allows the use of GPS data to create a personalised offer in real time.

4. USE OF MARKETING WEB METRICS IN THE INSURANCE INDUSTRY

The use of marketing web metrics in the insurance industry not only allows insurance companies to better understand their users, but also allows them to become more agile in their marketing strategies. Companies such as AXA, MetLife, Allianz and AIG are successfully using advanced data analysis techniques, predictive models and personalised marketing campaigns to improve

customer experience and increase their competitiveness in the market⁶⁹⁸. Through a better understanding of customer behaviours, insurance companies can optimise their marketing activities, reduce costs and increase conversion.

Example 1. Allianz⁶⁹⁹, a global insurance leader, uses marketing web metrics to create personalised offers for its customers. By using advanced analytical tools, Allianz monitors user behaviour on its website, identifies their needs (eg interest in car insurance) and generates targeted marketing content based on this data. By tracking those metrics, Allianz was able to increase conversion rates, as it offered users exactly what they were looking for at the right time.

Allianz implements data analysis tools such as Google Analytics, Adobe Analytics and internal data analysis systems that enable monitoring of user behaviour on their websites. This data includes information about what services users search for, how much time they spend on certain pages, and what questions they ask before making a decision to purchase an insurance product.⁷⁰⁰ Through user segmentation, Allianz is able to recognise different groups of consumers and offer them personalised services. For example, for users who have been interested in car insurance, Allianz may display special offers for cars of certain brands or types, using data about the user's previous interactions with the site.

Predictive analytics plays a key role in their marketing efforts. Based on past data, Allianz uses algorithms to predict which customer groups are most likely to purchase a particular insurance product. This data allows campaigns to be precisely targeted towards users who are likely to be interested in additional products. For example, if a user frequently searches for life insurance options, Allianz may automatically display ads for similar products such as health insurance or accident insurance.

Allianz also uses its CRM (Customer Relationship Management) systems in combination with web analytics to create a comprehensive view of customer interactions. CRM allows a company to track the history of customer interactions, from the first contact to the moment they make a decision to purchase a product. Linking this data with web metrics allows Allianz to build long-term, personalised customer relationships, which are key to retaining existing and attracting new customers.

⁶⁹⁸ Craffey & Ellis-Chadwick (2019), op. cit.

⁶⁹⁹ <https://www.allianz.com/>

⁷⁰⁰ Kaushik, A. (2010). *Web Analytics 2.0: The Art of Online Accountability and Science of Customer Centricity*. Wiley.

Example 2. AIG⁷⁰¹ is one of the global leaders in the insurance industry, and their application of marketing web metrics aims to improve the user experience on their website, improve conversion and optimize marketing campaigns. AIG uses Google Analytics and other advanced tools to track user interactions on its site. Through detailed monitoring of click-through rate (CTR), bounce rate and conversion rate, AIG can identify exactly which pages attract users and which cause them to leave the site. For example, AIG identified that site visitors often abandon the insurance application form at the stage where personal information is required. Based on that data, the company optimised the site design, simplified the sign-up process, added clear calls to action and reduced the number of steps required to fill out the form, leading to an increase in conversion rates.

AIG is focused on improving the mobile user experience. The data collected through web metrics helps them understand how users interact with mobile versions of their websites, as well as mobile applications. Based on that data, AIG improved the design of its mobile applications, allowing users easier access and a faster process of contracting insurance policies.

Using web metrics, AIG is able to develop multi-channel marketing campaigns that integrate digital and offline channels, such as TV ads, email marketing, social media and SEO optimization⁷⁰². AIG tracks how users behave after they come into contact with different ads, and by analysing their interactions, they can optimise which campaigns bring the best results.

For example, AIG can track how users who first interacted with an ad on social media later convert through their website, or how users who first watched an ad on TV search for their products online. These metrics help determine which marketing channels provide the highest ROI.

AIG uses A/B testing to test different versions of its web pages and marketing messages. For example, a company can test different headlines on its website, different calls-to-action, or even different insurance premium prices. By using web metrics, AIG can determine which version performs better in terms of conversion rate, thereby increasing the effectiveness of its marketing campaigns.

Example 3: AXA⁷⁰³ is another large international insurance company that uses digital tools and marketing web metrics to improve customer engagement and

⁷⁰¹ <https://www.aig.com/>

⁷⁰² Smith, P. R., & Zook, Z. (2016). *Marketing Communications: Integrating Offline and Online with Social Media*. Kogan Page.

⁷⁰³ <https://www.axa.com/>

conversion. AXA is known for using personalization and digital strategies to create relevant and timely offers for its customers.

AXA uses analytical tools such as Google Analytics and HubSpot to track user visits and analyze their interests. Using that data, AXA was able to personalize marketing messages and increase user engagement. For example, if a user visits a life insurance page, AXA may send automatically generated e-mail messages containing information about different life insurance plans, all in order to provide a personalised offer.

AXA conducts regular A/B testing on its website and digital ads to see which campaign variation works best. For example, they tested different insurance application page designs and found that a simpler form with fewer data entry fields performed significantly better in terms of conversion rate.

Similar to Allianz, AXA uses predictive analytics to predict which customers are likely to be interested in additional services, such as additional health insurance. Based on data about previous user interactions with their website, AXA creates automated campaigns that target users with a high potential to purchase those products. AXA also uses sentiment analysis techniques to track brand conversations on social media. Monitoring positive and negative comments on networks such as Twitter, Facebook, and LinkedIn helps them better understand how consumers perceive their products and services. By analyzing this data, AXA can adapt its approach and improve customer relations.

*Example 4: MetLife*⁷⁰⁴, one of the largest insurance brands in the world, uses web metrics marketing to integrate innovative technologies and create long-term relationships with its customers. This company focuses on connecting digital channels with offline interactions, thereby maximizing user reach and engagement.

MetLife uses mobile applications and web platforms to collect customer data in real time. Through the application, users can monitor the status of their policies, receive notifications about insurance expiration or even calculate the cost of new insurance packages. Using web metrics like user flow and funnel analysis, MetLife analyses user habits and optimises flows through applications to increase the number of active users.

Like other competitors, MetLife uses personalisation based on data it collects about user behaviour. For example, if a user frequently searches for life insurance

⁷⁰⁴ <https://www.metlife.com/>

products, MetLife will use that data to display relevant ads or offers on the Internet, through mobile applications, or even through personalised email messages. This approach increases the likelihood that users will make a final purchase decision.

MetLife is a pioneer in integrating digital and traditional marketing channels. They use email marketing, SEO, Google Ads, as well as offline channels like TV commercials and radio spots. By using data analysis and metrics such as customer journey and cross-channel attribution, MetLife can better understand how customers behave throughout the decision-making process and optimize its marketing activities accordingly⁷⁰⁵.

One of the interesting aspects of the application of marketing web metrics at MetLife is the use of data to optimize the price of insurance policies. Based on data collected from users browsing the site or contacting customer support, MetLife can test different price points and offers to determine the optimal price level that elicits the best response from users and increases sales.

A useful direction for future research is the degree of use of web marketing metrics by insurance companies in the Republic of Serbia, comparison of the achieved level with use in developed economies and the adoption of good practice.

⁷⁰⁵ <https://www2.deloitte.com/>

DEVELOPING A CORPORATE GOVERNANCE EXPERT SYSTEM WITH APPLICATIONS IN THE INSURANCE INDUSTRY

The insurance sector, though traditionally cautious in adopting new approaches, relies heavily on the effective handling of vast datasets, making it well-suited for digital innovation. The data-centric nature of the industry positions it at the forefront of digital transformation efforts. Indić and Urošević⁷⁰⁶ highlight the role of digitalization in reshaping insurance, while Urošević and Radak⁷⁰⁷ emphasize the growing importance of ESG compliance. Both of these trends are reshaping the industry and call for the adoption of advanced technologies to manage data more efficiently. Additionally, the use of sophisticated algorithms is becoming increasingly important for investment strategies and asset allocation decisions within insurance firms, as noted by Drenovak et al.⁷⁰⁸ Urošević and Šaletić discuss the role of Generative Artificial Intelligence (Generative AI) in insurance⁷⁰⁹ building up on the discussion by Pavlović B.⁷¹⁰

In this chapter we discuss development of a corporate governance expert system with its application in the insurance industry. An expert system is a computer program designed to simulate the decision-making abilities of a human expert in a specific domain. It utilizes a knowledge base containing facts and heuristics,

⁷⁰⁶ Indić, D., & Urošević, B. (2021). Emerging Digital Insurance. In: *Contemporary Challenges and sustainability of the insurance industry*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 249-264.

⁷⁰⁷ Urošević, B., & Radak, V. (2022). ESG Challenges and Opportunities in the Insurance Market. In: *Development of modern insurance market – constraints and possibilities*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 219-235.

⁷⁰⁸ Drenovak, M., Ranković, V., Urošević, B., & Jelic, R (2021). Bond Portfolio Management under Solvency II Regulation. *The European Journal of Finance*, 27(9), pp. 857-879.

⁷⁰⁹ Urošević, B. & Šaletić, S. (2024). Generative AI and Insurance. In: *Transformation of the insurance market – responses to new challenges*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 267-290.

⁷¹⁰ Pavlović, B. (2023). Application of ChatGPT in Insurance. In: *Challenges and Insurance Market's Response to the Economic Crisis*, Kočović, J. et al. (eds.), Belgrade: University of Belgrade, Faculty of Economics and Business, pp. 455-473.

and an inference engine that applies logical rules to the knowledge base to deduce new information or make decisions. These systems are employed to solve complex problems by reasoning through bodies of knowledge, rather than by following procedural code. The system described here represents a real project currently in development, with core functionalities already operational and fully capable of processing data. Early testing with the initial users has demonstrated the practical viability of the approach, while development continues to expand the system's capabilities.

Expert Systems in the Insurance Industry:

In the insurance sector, expert systems have been utilized to enhance various processes:

- *Claims Processing and Settlement:* Expert systems automate the evaluation of claims, ensuring faster and more accurate settlements by analyzing policy conditions and claim details.⁷¹¹
- *Fraud Detection and Prevention:* By identifying patterns and anomalies in claims data, expert systems assist in detecting fraudulent activities, thereby reducing financial losses.
- *Underwriting and Risk Assessment:* These systems evaluate applicant risk profiles and predict potential losses, aiding underwriters in making informed decisions.

One interesting example is the development of an expert system for detecting automobile insurance fraud using social network analysis, which focuses on identifying groups of collaborating fraudsters⁷¹².

Expert Systems in Corporate Governance:

The application of expert systems in corporate governance is less prevalent but emerging. They are utilized to ensure compliance with governance standards and to assess corporate governance performance:

- *Governance Performance Ratings:* Machine learning techniques have been employed to develop governance performance ratings based on companies' adherence to governance responsibilities, providing a predictive assessment of governance quality.⁷¹³

⁷¹¹ https://www.spear-tech.com/7-game-changing-applications-of-expert-systems-in-insurance/?utm_source=chatgpt.com

⁷¹² <https://arxiv.org/pdf/1104.3904>

⁷¹³ <https://onlinelibrary.wiley.com/doi/10.1002/isaf.1505>

- *Regulatory Compliance:* Expert systems can automate the monitoring of compliance with corporate governance codes and regulations, ensuring that organizations adhere to required standards.⁷¹⁴ While specific implementations are not extensively documented, the integration of expert systems in corporate governance is anticipated to grow as organizations seek more robust compliance and governance frameworks.

We see, therefore, that expert systems are already playing a role in the insurance industry by automating complex processes like claims assessment and fraud detection. Their application in corporate governance, though currently limited, holds potential for enhancing compliance and performance evaluation.

The insurance industry operates within a complex regulatory and governance framework where analytical rigor and quantitative precision must coexist with qualitative judgment. For actuaries, whose work inherently bridges quantitative modeling with business decision-making, the limitations of current governance assessment approaches present a significant challenge. This chapter introduces a novel expert system that integrates probabilistic and deterministic assessment methodologies to enhance governance evaluation in insurance enterprises.

Current governance assessment methodologies in the sector are characterized by a bifurcation between purely quantitative approaches (statistical models and machine learning algorithms analyzing numerical metrics) and qualitative methodologies (traditional expert judgment or natural language processing interpreting regulatory documents). The quantitative-qualitative division can be problematic in insurance, where effective governance relies on both statistical significance and contextual interpretation.

The proposed expert system synthesizes rule-based validation techniques familiar to actuaries with advanced interpretive capabilities of Large Language Models (LLMs). This dual approach addresses challenges specific to insurance governance, including the evaluation of oversight mechanisms for reserve adequacy, underwriting authority frameworks, risk management effectiveness, and the alignment of financial incentives with long-term solvency protection.

In his famous paper titled “Science and Statistics”⁷¹⁵, British statistician George Box famously asserted that “All models are wrong, but some are useful”. This has later become known as the Box's principle. Actuaries are certainly quite

⁷¹⁴<https://www.expertsystems.com.hk/wp-content/uploads/2024/07/E-2024-Annual-Report.pdf>

⁷¹⁵ Box, G. (1976). Science and Statistics. *Journal of the American Statistical Association*, 71(356), pp. 791-799.

familiar with this concept. Namely, actuarial science has long recognized that even the most sophisticated models incorporate simplifying assumptions that limit their fidelity to complex systems. When evaluating insurance operations, no single model can capture all relevant dynamics. Statistical frameworks offer mathematical precision but often abstract from human behavioral factors, while qualitative models provide contextual understanding but may lack the systematic rigor required for consistent evaluation.

The integrated approach proposed here acknowledges these complementary limitations. Rather than pursuing an illusory perfect representation, it creates a more robust analytical framework. When examining risk governance, for example, statistical analysis might identify outlier patterns in committee compositions and meeting frequencies, while textual analysis reveals substantive variations in risk discussions that correlate with subsequent operational outcomes.

A distinguishing feature of the system that we describe here is its capacity for continuous calibration through real-time data integration. This dynamic capability is particularly valuable for actuarial applications, where model recalibration in response to emerging experience is a core practice. The system can update governance assessments as regulatory requirements, market conditions, and industry standards evolve, maintaining analytical relevance in a changing environment.

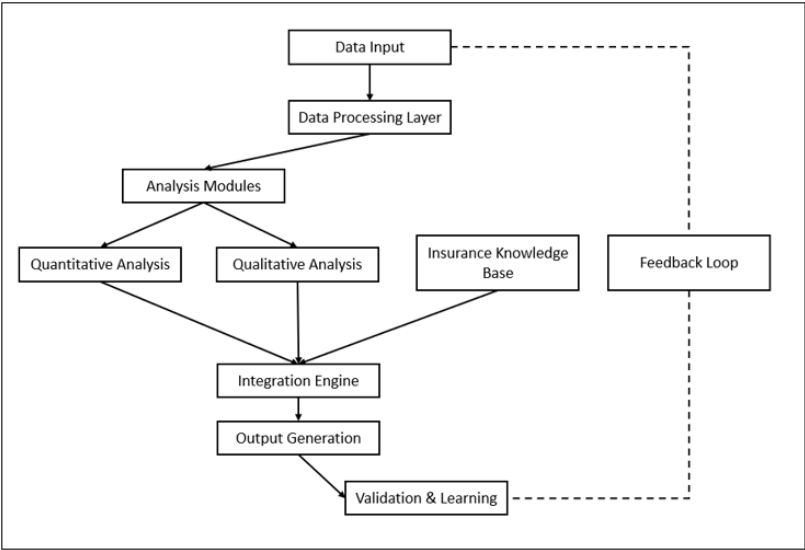
This research holds practical relevance for a range of stakeholders in the insurance industry. For actuaries in particular, the expert system offers a standardized approach to assessing governance structures related to reserve adequacy, pricing, and model risk management. By combining quantitative metrics with qualitative insights, it delivers a more holistic and consistent evaluation of governance effectiveness than fragmented methods currently allow. The remainder of the chapter is organized as follows: Section 1 outlines the system's integrated architecture; Section 2 describes the data organization strategy that supports robust analysis and mitigates hallucinations; Section 3 illustrates governance risk factors the system can detect; Section 4 discusses its role in training and knowledge transfer; and Section 5 reviews its potential for regulatory compliance and adaptability.

1. INTEGRATED SYSTEM ARCHITECTURE

The expert system framework presented here processes both qualitative and quantitative data, allowing it to address diverse governance challenges and adapt to various analytical needs across industries. Unlike traditional tools like the ISS

Corporate Governance Quotient (CGQ) or S&P’s Governance Scorecard, which rely on standardized metrics, this system incorporates industry-specific risks, regulatory contexts, and stakeholder dynamics to deliver more tailored governance assessments. Figure 1 illustrates the system’s architecture and data flow. At its core, the framework merges metrics and qualitative evaluations to offer a holistic view of governance - especially critical in insurance, where conventional metrics often overlook issues like reserve adequacy, underwriting authority, and actuarial independence. Each system component transforms raw data into actionable insights, with particular emphasis on insurers' fiduciary duties and their long-term obligations to policyholders. The following sections describe the role of each component in the overall system.

Figure 1. Architecture of the corporate governance expert system framework



Data Inputs

The system is envisioned to take as inputs multiple data sources including regulatory filings, board materials, oversight documents, compensation plans, industry benchmarks, and regulatory updates across multiple languages. These diverse inputs ensure a holistic view of an organization's operational and strategic management landscape. The system's multilingual capabilities are enabled by its use of Large Language Models (LLMs) in the qualitative analysis module, allowing for comprehensive governance assessment regardless of the source document's language. This is particularly valuable for organizations operating across multiple jurisdictions where governance documentation and regulatory requirements may exist in different languages.

Data Processing Layer

Raw data is transformed into structured formats through a comprehensive processing pipeline comprising information extraction, data normalization, and the standardization of metrics and terminology. The system is designed to handle a wide range of document types - including PDFs, spreadsheets, text files, and HTML - converting unstructured content into standardized, analyzable data points. This process supports the generation of consistent metrics and comparable governance indicators, enabling uniform application across organizations, regions, and industry sectors, while accounting for their specific governance frameworks and reporting standards.

Quantitative Analysis Module

This module applies rule-based validation to critical governance metrics, including board independence ratios, committee composition patterns, executive compensation structures, and regulatory compliance statistics. The system performs real-time statistical comparisons against industry benchmarks, identifies anomalies and threshold violations, and processes, whenever possible, high-frequency data to detect emerging governance trends⁷¹⁶. For insurance companies, this includes specialized metrics related to risk committee effectiveness and capital adequacy oversight.

Qualitative Analysis Module

Using Large Language Model (LLM) capabilities, this module is tasked to interpret textual documents, evaluate the quality of leadership communications, assess organizational culture indicators, and analyze the strategic alignment of structures with the insurer's risk profile. It should provide the context for the quantitative metrics by examining the underlying practices and actual implementation behind formal organizational structures.

Integration Engine

A key innovation of the proposed system lies in its Integration Engine, which combines quantitative measurements with qualitative insights through a sophisticated weighting algorithm. When quantitative metrics indicate potential issues, the qualitative analysis offers contextual interpretation and explanatory depth. Conversely, qualitative red flags are cross-validated against quantitative indicators. This bidirectional integration enables a more nuanced and robust assessment of governance effectiveness than either approach could achieve independently.

⁷¹⁶ Kustudic, M., & Niu, B. (2024). Stata tip 155: How to perform high-frequency event studies. *The Stata Journal*, 24(2), pp. 362-368, <https://doi.org/10.1177/1536867X241258013>

Insurance Knowledge Base

The repository is designed to encompass industry-specific principles and guidelines, jurisdictional regulatory requirements, risk profile templates tailored to various insurance business models, and historical case studies of operational failures. This knowledge base enhances the system's ability to calibrate analyses to the distinctive features of the insurance sector, where governance oversight has direct implications for policyholder protection and long-term liability management. Access to such a comprehensive body of global insurance knowledge benefits not only multinational insurers but also regional and local firms seeking to align with best practices and evolving regulatory standards.

The Output Generation

The system generates comprehensive corporate governance assessment reports, prioritized recommendations, tailored explanations, and visual dashboards. Outputs are customized for various stakeholders - for example, board members receive strategic insights, while compliance teams are provided with detailed analyses of regulatory alignment.

Validation & Learning

Through ongoing comparison of system assessments with the actual outcomes and incorporation of human expert feedback, the system continuously refines its analysis parameters and weighting algorithms. This ensures that the system evolves as the standards and insurance industry practices change and evolve over time.

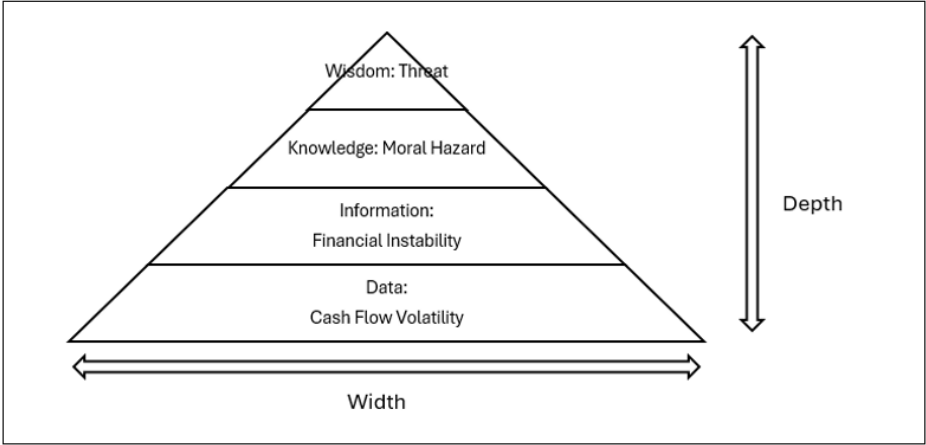
The key advantage of such an expert system is its ability to bridge the gap between pure compliance checking and contextual quality assessment, particularly important in insurance where organizational failures can have significant consequences for policyholders, not just shareholders.

2. HERAS DATA ORGANIZATION METHODOLOGY

While the expert system framework provides the architectural foundation for insurance governance assessment, its effectiveness hinges on the organization, transformation, and interpretation of data. Addressing the complexity of insurance-specific governance issues requires a robust data organization strategy capable of integrating diverse sources - from structured regulatory filings to unstructured board communications and industry benchmarks. To generate meaningful insights on topics such as actuarial independence, underwriting authority, and reinsurance governance, raw data must be systematically transformed into higher-order knowledge. The HERAS (Hybrid Echelon Rule Assessment System) framework, originally developed for financial analysis,

offers a suitable methodology due to its emphasis on hierarchical knowledge transformation and hallucination prevention. Adapted to the insurance domain, HERAS ensures assessments remain factually grounded while leveraging the interpretive strengths of advanced language models.

Figure 2. The DIKW pyramid structure and dimensional analysis



The HERAS framework is grounded in the Data-Information-Knowledge-Wisdom (DIKW) pyramid, depicted in Figure 2 - a hierarchical model that captures the transformation of raw data into actionable wisdom. In this model, data represents unprocessed facts; information arises from organizing data according to defined principles; knowledge reflects the interpretation of this information; and wisdom denotes its effective application in decision-making. Widely adopted across disciplines, the DIKW model offers both breadth and analytical depth, enabling comprehensive evaluation of data richness and interrelationships. In the context of insurance governance, the width dimension reflects the variety of available data points, while the depth dimension captures the explanatory detail and conceptual clarity. This structured progression underpins our expert system’s capacity to convert raw inputs into meaningful governance insights.

The Width (Breadth) Dimension

The width dimension of the DIKW pyramid captures the breadth of data points and sources integrated into the analysis. In the context of insurance governance assessment, it encompasses a diverse array of governance indicators, regulatory requirements, stakeholder perspectives, and contextual variables. A robust width ensures that the system evaluates factors across multiple domains, minimizing the risk of overlooking elements critical to governance quality. Specifically, for insurers, this includes coverage across various business lines - such as property

and casualty, life, health, and reinsurance - as well as across jurisdictions and regulatory frameworks.

The expert system's ability to synthesize data from heterogeneous sources - financial statements, board documents, regulatory communications, industry benchmarks, and stakeholder inputs - enables a comprehensive, multidimensional view of governance. This horizontal integration is essential for identifying cross-cutting governance issues that may remain hidden under narrower, siloed analyses.

The Depth Dimension

While *width* captures the breadth of coverage, the *depth* dimension reflects the level of detail and explanatory richness at each layer of the governance pyramid. It describes how thoroughly the system investigates each element - ranging from surface metrics to deeper insights into root causes and implications. At the data level, depth may involve granular historical trends; at the information level, it includes contextual drivers of those metrics.

As the system advances toward knowledge and wisdom, depth emerges through increasingly refined interpretations. Rather than merely flagging issues, it enables comprehensive analyses of underlying factors, potential consequences, and interdependence. For example, in actuarial governance, depth allows not only identification of structures ensuring actuary independence but also assessment of report quality, actuary-management interactions, and patterns suggesting potential pressures on actuarial judgment.

The Integrative Approach

Integrating the width and depth dimensions enables a matrix-based approach to governance assessment that addresses the limitations of traditional methods. Quantitative approaches typically offer broad coverage but limited explanatory depth, while qualitative methods provide depth on specific issues yet often lack consistent breadth.

The proposed framework harnesses this dimensional integration to achieve both comprehensive scope and analytical depth. By moving horizontally across domains vertically through analytical levels, it produces a three-dimensional assessment that captures the complexity of insurance governance while remaining practical and actionable for decision-makers.

Implementation Procedure

To implement the HERAS framework, the first step is to define the *axioms* - core rules encoded within a classical rule-based system. These axioms represent key

elements the system verifies, and once validated, they help prevent hallucinations commonly associated with LLM-based systems (see, e.g., Urošević and Šaletić, 2024). While rule creation can be somewhat labor-intensive, LLMs can assist by processing extensive academic literature to support this task. At this stage, a vetted knowledge base can be integrated using the RAG (Retrieval-Augmented Generation) technique for LLMs⁷¹⁷. This two-step process first retrieves relevant documents, rules, and precedents from a curated governance knowledge base in response to a query. The LLM then generates responses using both the retrieved content and its general capabilities.

This approach offers two main advantages: it extends access to specialized governance knowledge beyond the LLM’s original training data and substantially reduces hallucination risk by grounding outputs in verified information.

For a concrete example of dataflow, consider an example of an axiom such as moral hazard, which is a well-established issue in finance and insurance. Its main characteristics and explanations can be loaded into RAG database. According to financial literature the implications of moral hazard are as follows⁷¹⁸:

- *Perceived Safety Net*: When a company is perceived as “too big to fail” or is believed to have government support in times of crisis, management may feel less accountable for taking risky decisions.
- *Short-Term Focus*: In volatile environments, companies may prioritize short-term gains over long-term sustainability, leading to riskier behaviors.
- *Managerial Incentives*: In some cases, executive compensation may be tied to short-term performance, encouraging excessive risk-taking to boost the value of executive compensation packages such as stock options.

Indicators of moral hazard can be detected through specific financial metrics and behavioral patterns. Notably, cash flow volatility and signs of financial instability often signal excessive risk-taking. Such patterns may include erratic cash flows diverging from industry benchmarks, abrupt increases in risky activities threatening long-term viability, and financial decisions favoring short-term gains over sustainable performance.

⁷¹⁷ Lewis P. et al. (2020). Retrieval-augmented generation for knowledge-intensive NLP tasks. In: *Proceedings of the 34th International Conference on Neural Information Processing Systems*, Red Hook, NY: Curran Associates Inc., pp. 9459-9474.

⁷¹⁸ <https://corpgov.law.harvard.edu/2023/10/23/the-ceo-shareholder-straightforward-rewards-for-long-term-performance/>

These patterns can be quantitatively assessed using cash flow volatility metrics. For publicly traded U.S. firms, this analysis leverages standardized financial data from SEC filings, particularly the Statement of Cash Flows in Forms 10-K and 10-Q. These reports enable systematic tracking of cash flow trends and the identification of potential moral hazard signals.

The concept of the top echelon - *wisdom* - is defined by Merriam-Webster as the ability to discern inner qualities and relationships (insight) and to exercise sound judgment⁷¹⁹. Central to this definition is the emphasis on relationships and the alignment of factors with universal values. These aspects can be examined using various methods, including AI algorithms and econometric techniques. The resulting insights can then be evaluated against established breakpoints or dynamic benchmarks and thresholds for validation and comparison.

When the system's algorithms identify a critical condition, the LLM component offers a multi-layered contextual interpretation. First, it explains the reasoning behind the conclusion, outlining the analytical methods used and patterns observed in the data. Second, it assesses temporal dynamics by comparing current metrics with historical benchmarks, highlighting key deviations and trends. Third, it delivers comparative insights by referencing similar cases, such as peer companies that encountered related governance issues.

These explanatory features are highly adaptable, offering in-depth technical analyses for governance experts and concise summaries for board members and executives. This flexibility ensures that complex governance findings remain both accessible and actionable across all organizational levels. A visual summary of this process is shown in Figure 1. To understand what each element of the framework represents we can consider Table 1.

As shown in Table 1, each level of the HERAS framework plays a distinct role in the governance assessment process, moving systematically from raw data collection to the generation of actionable insights. In the insurance sector, this layered approach proves especially useful for analyzing complex governance arrangements involving diverse stakeholders with varying interests. For instance, at the Data level, the system may gather details on the composition of an insurer's risk committee. At the Information level, it processes this data into metrics - for example, the proportion of members with specific technical expertise. The Knowledge level then applies insurance-relevant benchmarks to assess whether the committee's structure aligns with the insurer's risk profile and business lines. Finally, at the Wisdom level, the system can highlight emerging governance

⁷¹⁹ <https://www.merriam-webster.com/dictionary/wisdom>

concerns, such as limited actuarial representation or gaps in catastrophe risk oversight, before these issues escalate. This structured progression ensures that governance evaluations are grounded in objective evidence while enabling the nuanced interpretation needed for effective recommendations.

Table 1. Classification of key framework elements in corporate governance analysis

Echelon	Purpose	Feature	Use
Data	Raw data or information used for calculations	May not have a direct semantic meaning	Link to data source and input for calculations
Information	A measure with a topic-related meaning	Can be a singleton or a composite, combining multiple pieces of data/information	Governance proxy measure
Knowledge	The specific subject matter identified in evidence	Applies indicators to evaluate governance effects and outcomes	Link to evidence and evaluation logic
Wisdom	A binary indicator (yes/no/NA) signaling a potential threat	Linked to a specific knowledge factor but separated for reporting and analysis	Red flag detection and justification

Here are some of the important aspects of the implementations that improve the quality of the system and its usefulness:

- *Data Efficiency*: LLMs can transform raw data into actionable insights, reducing redundancy and improving data quality.
- *Data Enrichment*: Large Language Models (LLMs) enhance data quality by integrating information from diverse sources to produce richer, more insightful datasets. The system draws on a wide range of inputs, including the latest academic research on governance, insurance, and the financial sector, as well as real-time and historical data on significant industry events, among others.
- *Accessibility and Clarity of Insights*: LLMs translate complex governance data into clear, understandable insights tailored to a wide range of stakeholders - from board members and executives to compliance officers, risk managers, and regulators - ensuring that essential governance findings are actionable across all levels of the organization.
- *Efficiency*: Automated analysis streamlines the corporate governance assessment process, substantially reducing the time and resources

needed. This enables governance professionals to shift their focus from manual data handling to higher-value strategic interpretation.

- *Reliability*: The solution addresses the issue of LLM hallucinations, ensuring its safe and reliable use in expert-level financial domains.

A significant benefit of HERAS system is its adaptability. It can be implemented in any location using locally fine-tuned LLMs. This approach does not require sending potentially classified data to outsiders that can misuse it, and it adheres to all data privacy and security regulations and company policies.

The system's advantages directly address key challenges in insurance governance assessment. Insurers operate in highly regulated environments with complex, cross-jurisdictional compliance demands and specialized oversight needs in areas such as underwriting, claims, and actuarial valuation. Applying this framework enables automated analysis of governance structures against insurance-specific regulations, integration of qualitative cultural insights with quantitative compliance metrics, and tailored explanations aligned with insurers' fiduciary duties to policyholders. It can uncover governance gaps that might otherwise be overlooked - such as weak board oversight of reserve adequacy, blurred lines between underwriting and claims, or structures misaligned with long-term solvency goals. Additionally, the system offers streamlined access to cutting-edge governance best practices.

3. EXAMPLES OF GOVERNANCE RISK FACTORS

Initial testing of the expert system has yielded promising outcomes across a range of governance scenarios. By integrating advanced AI techniques with established analytical approaches, the system effectively detects and interprets governance risk factors. Table 2 highlights key examples of governance issues identified by the framework, accompanied by detailed insights into their potential consequences. While these early results are encouraging, ongoing development is focused on enhancing the system's capabilities - particularly in benchmark analysis and peer comparisons. These advancements aim to support broader market-level governance assessments through more sophisticated data processing and comparative analytics.

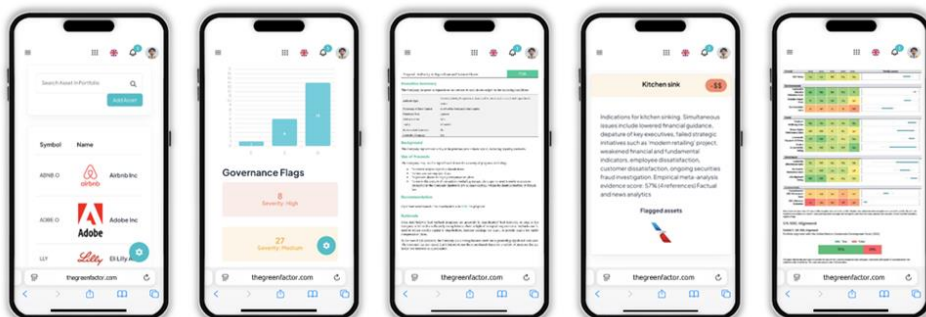
Table 2. Common corporate leadership structure issues and their implications

Chairman is ex-CEO The company may face potential issues related to power and influence if the chairman has previously held the CEO position. Namely, this could lead to entrenchment and lack of scrutiny related to the past leadership decisions. The lack of separation between the roles of CEO and the Chairman of the Board can also compromise board independence and hinder effective oversight. This can result in a lack of checks and balances within the company's governance structure.
CEO Board Member The company may face potential conflicts of interest when the CEO holds a position on the board of directors, as their personal interests may take priority over the concerns of shareholders and stakeholders. This can lead to biased decision-making and a lack of accountability within the company's leadership structure. The CEO's dual role can also compromise the board's independence and ability to provide effective oversight. This highlights the importance of maintaining a clear separation between the CEO's role and the board's responsibilities to ensure fair and transparent governance within the organization.
CEO Chairman Duality The company's flag is a warning sign that the CEO may also be the chairman of the board or that the previous CEO is now the chairman. This lack of separation of powers can lead to conflicts of interest, limited diversity of perspectives, and a lack of accountability and oversight. It also increases the risk of decisions being made for the benefit of the CEO rather than the company as a whole and can result in decreased transparency and unchecked unethical behavior.

The examples in Table 2. demonstrate how our expert system framework can be practically applied to uncover governance vulnerabilities. Although the system is designed for corporate governance assessment broadly, we believe its methodology holds particular promise when tailored to the insurance sector's distinct challenges. Insurers stand to benefit from its capacity to evaluate specialized governance structures - such as ensuring actuarial independence, assessing the delegation of underwriting authority, and analyzing the alignment between risk appetite and capital adequacy oversight.

Figure 3 presents the user interface of our expert system, highlighting its mobile-responsive design across five key screens. The interface guides users from the initial company selection (leftmost screen) through various stages of governance analysis - visualizing quantitative metrics (second screen), capturing qualitative assessments (middle screen), and identifying specific risk factors (fourth screen). The rightmost screen features a comprehensive governance scorecard, employing a color-coded scheme to clearly indicate strengths (green) and areas of concern (red). This user-friendly layout ensures that even complex governance evaluations remain both accessible and actionable, while preserving the analytical depth needed for robust decision-making.

Figure 3. Different mobile interfaces for different analyses



The system's flexible architecture supports a variety of deployment models to accommodate diverse market needs. Its modular design allows for seamless integration with existing financial platforms and fintech solutions through standardized APIs, enabling governance analytics to be embedded directly into established workflows. For organizations with specialized requirements, custom development services are available to tailor the system to unique governance frameworks and reporting standards. This multi-channel approach ensures that institutions of all sizes and complexities can effectively harness the platform's integrated governance and portfolio management capabilities.^{720,721}

As regulatory demands continue to evolve, future development of the system will focus on broadening its knowledge base to address emerging governance

⁷²⁰ Hao, Z., Yang, C., Liu, L., Kustudic, M., & Niu, B. (2020). Exploiting skew-adaptive delimitation mechanism for learning expressive classification rules. *Applied Intelligence*, 50, pp. 746-758.

⁷²¹ Niu, B., Xue, B., Zhou, T., Kustudic, M. (2019). Aviation maintenance technician scheduling with personnel satisfaction based on interactive multi-swarm bacterial foraging optimization. *International Journal of Intelligent Systems*, 37, pp. 723-747.

challenges - such as climate risk disclosure mandates, cyber insurance governance frameworks, and the integration of InsurTech into traditional oversight structures, among others. By combining quantitative evaluation with nuanced qualitative interpretation, the system offers insurers, regulators, and investors a more holistic perspective on governance effectiveness than previously possible with fragmented methods.

By bridging the gap between rule-based compliance checks and context-driven assessments of governance quality, this expert system marks a significant step forward in insurance governance technology. It recognizes the need to balance technical rigor with human judgment in an industry where governance shortcomings can carry profound consequences for policyholders and overall financial stability.

4. TRAINING AND KNOWLEDGE DISSEMINATION

An essential but often overlooked application of an integrated expert system lies in its ability to transform corporate governance education and training across the insurance enterprise. Traditional governance training approaches typically rely on standardized materials that fail to address the unique challenges faced by different stakeholders within the organization. Our expert system addresses this limitation by leveraging both quantitative metrics and qualitative assessments to create personalized, context-aware training experiences.

Dynamic Training Material Generation

The expert system can automatically generate training materials tailored to specific roles, responsibilities, and knowledge gaps within the insurance organization. For board members, the system might produce detailed explainers on actuarial independence and its governance implications, while for underwriting managers, it could focus on delegation of authority frameworks and their relationship to enterprise risk appetite. This dynamic content generation would ensure that training resources remain relevant, up-to-date, and aligned with both the regulatory requirements and organizational needs.

By analyzing governance documentation, regulatory changes, and industry best practices, the system can continuously refresh the training content to reflect the evolving landscape of the insurance governance. This eliminates the common problem of outdated training materials that fail to address emerging risks or regulatory developments.

Personalized Learning Pathways

Beyond simply generating content, the expert system can identify individual knowledge gaps through the assessment of governance-related activities and interactions. For new board members, the system might recommend foundational training on insurance-specific fiduciary duties, while for experienced directors, it could suggest advanced modules on emerging risks such as climate change governance or cyber resilience oversight.

This personalization extends to learning formats as well. The system can determine whether individuals respond better to case studies, interactive scenarios, or detailed technical explanations, and adjust the content delivery accordingly. For technical specialists, the system might emphasize quantitative governance metrics and their interpretation, while for non-technical stakeholders, it could focus on qualitative explanations and practical applications.

Simulation and Scenario Testing

One of the most powerful applications of the expert system in governance education is its ability to generate realistic governance scenarios for training and testing. The system can create simulated board meetings, regulatory examinations, or crisis response situations that require participants to apply governance principles in practice. These simulations draw from both the historical governance failures and synthetically generated scenarios based on the organization's specific risk profile. By exposing participants to challenging decisions in a controlled environment, the system helps build muscle memory that can be invaluable during actual challenges⁷²².

The integration of quantitative metrics and qualitative assessments is particularly valuable in these simulations. Participants must consider both the hard data (capital ratios, risk concentrations, compliance statistics) and soft factors (leadership dynamics, stakeholder expectations, reputation considerations) in their decision-making, mirroring the complexity of real-world governance challenges in insurance.

Continuous Improvement Through Feedback Loop

The expert system maintains a continuous feedback loop between the governance performance and training effectiveness. When governance weaknesses are identified through the system's monitoring capabilities, corresponding training modules can be automatically flagged for review and enhancement. Similarly,

⁷²² Kustudic, M., Niu, B., & Liu, Q. (2021). Agent-based analysis of contagion events according to sourcing locations. *Scientific Reports*, 11, 16032.

when participants struggle with concepts or scenarios during the training, the system can adapt future governance monitoring to pay particular attention to those areas. This integrated approach ensures that governance training is not treated as a standalone compliance exercise but as an integral part of the organization's overall governance framework. By connecting training directly to governance outcomes, the expert system helps transform governance education from a periodic obligation into a continuous improvement process that strengthens the organization's governance capabilities over time.

5. REGULATORY COMPLIANCE AND ADAPTATION

The insurance industry operates in an environment of frequent regulatory changes, with requirements that vary significantly across jurisdictions and across different lines of business. This regulatory complexity presents a serious challenge for governance structures, particularly as insurers expand across borders and business lines. The expert system's architecture directly addresses this challenge through specialized capabilities for regulatory compliance assessment and adaptation.

Dynamic Regulatory Mapping

A distinguishing feature of our system is its ability to create and maintain dynamic regulatory maps that connect governance practices to specific regulatory requirements across multiple jurisdictions. Unlike the traditional compliance approaches that treat regulations as isolated requirements, our system identifies interconnections between different regulatory frameworks and highlights areas of overlap and divergence.

For insurance companies operating across multiple jurisdictions, this mapping capability enables a more efficient approach to compliance. Rather than developing separate governance structures for each regulatory regime, the system identifies governance arrangements that simultaneously satisfy multiple regulatory requirements. For example, the system might determine that a particular board committee structure satisfies both Solvency II requirements in

Europe⁷²³ and NAIC Model Act⁷²⁴ provisions in the United States, enabling a more streamlined governance approach.

The integration of quantitative and qualitative analysis is particularly valuable in this context. Quantitative metrics validate compliance with specific numerical thresholds and reporting requirements, while qualitative assessment evaluates the effectiveness of governance arrangements in fulfilling the underlying regulatory intent. This dual analysis ensures that governance structures not only meet technical compliance standards but also embody the principles and objectives that motivated the regulatory requirements.

Regulatory Horizon Scanning

Beyond thoroughly checking for compliance with the current regulatory requirements, the expert system incorporates, also, forward-looking capabilities that enable insurers to prepare for emerging regulatory developments. The system continuously analyzes regulatory consultation papers, proposed rules, enforcement actions, and industry guidance to identify trends and anticipate future requirements.

Through natural language processing of regulatory communications and assessment of implementation timelines, the system generates early warnings about governance adaptations that may be necessary. This proactive approach to regulatory change management allows insurance companies to incorporate emerging requirements into their strategic planning rather than responding reactively to new mandates.

The system's integrated analytical approach is especially well-suited for assessing principles-based regulations - an approach increasingly favored in the insurance industry. Unlike rules-based frameworks, these regulations require insurers to demonstrate how their governance practices fulfill broad regulatory objectives, rather than simply adhering to prescriptive requirements. For instance, rather than dictating a specific board structure, such regulations may call for evidence that governance arrangements effectively manage risk and safeguard policyholder interests.

⁷²³ Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II). *Official Journal of the European Communities*, 2009/138/EC

⁷²⁴ National Association of Insurance Commissioners (NAIC) Corporate Governance Annual Disclosure Model Act (#305) and NAIC Corporate Governance Annual Disclosure Model Regulation (#306), adopted 2014.

While quantitative analysis can identify specific metrics that may be affected by regulatory changes, qualitative assessment evaluates how well the organization's governance culture aligns with regulatory principles and identifies potential areas of friction or misalignment.

Proportionality Assessment

An important challenge in insurance regulation is the concept of proportionality - the principle that governance requirements should be calibrated to the size, complexity, and risk profile of the insurer. Our expert system incorporates proportionality assessment capabilities that help insurers develop governance arrangements appropriate to their specific circumstances while remaining in compliance with regulatory requirements.

The system analyzes an insurer's business model, risk exposures, and organizational structure to determine the appropriate level of governance formality and complexity. For smaller insurers with relatively simple business models, the system might recommend streamlined governance structures that meet regulatory requirements without imposing unnecessary administrative burden. For complex global insurers with diverse business lines, the system would identify areas where more robust governance mechanisms are necessary to address heightened risks and regulatory scrutiny.

This proportionality assessment relies heavily on the integration of quantitative and qualitative factors. Quantitative metrics, such as premium volume, capital levels, and risk concentrations, establish the basic parameters for proportionality. In contrast, a qualitative assessment evaluates factors like business complexity, systemic importance, and stakeholder relationships that influence the appropriate governance intensity.

Cross-Functional Compliance Integration

Effective governance requires coordination across multiple organizational functions, each with its own regulatory compliance obligations. The expert system facilitates this coordination through cross-functional compliance integration that identifies relationships between governance requirements in different domains.

For instance, the system can evaluate how actuarial governance relates to both financial reporting compliance and product development oversight, helping insurers develop integrated governance structures that address multiple regulatory concerns simultaneously. This holistic approach prevents the development of governance silos that can lead to inconsistent practices or compliance gaps.

The integration of quantitative and qualitative analysis is essential for this cross-functional assessment. Quantitative metrics track specific compliance requirements across functions, while qualitative analysis evaluates how well these functions coordinate and communicate on governance matters. This dual perspective ensures that governance structures not only satisfy specific regulatory requirements but also operate effectively as an integrated system.

Regulatory Examination Preparation

Insurance regulatory examinations represent a significant investment of organizational resources and can have material consequences for an insurer's reputation and operational flexibility. Our expert system includes specialized capabilities for regulatory examination preparation that help insurers evaluate their governance practices through the lens of regulatory priorities and concerns.

The system analyzes recent examination findings, regulatory emphasis areas, and industry developments to identify potential areas of regulatory focus. It then evaluates the insurer's governance arrangements against these priorities, highlighting areas that may warrant additional attention or documentation before an examination. This proactive approach helps insurers address potential concerns before they become examination findings, reducing regulatory risk and improving examination outcomes.

The combination of quantitative and qualitative analysis provides particularly valuable insights in this context. Quantitative metrics identify specific compliance gaps or anomalies that might trigger regulatory concerns, while qualitative assessment evaluates whether governance practices align with regulatory expectations for effectiveness and prudence. This integrated approach ensures that insurers are prepared to demonstrate both technical compliance and governance substance during regulatory examinations.

The expert system framework proposed in this chapter has undergone the initial testing, showing promising results in real-world governance assessment scenarios. While still under active development, the system has demonstrated the potential to support multiple users and process governance data from diverse sources and jurisdictions. Early-stage deployments suggest that both the technical architecture and the HERAS methodology are on a strong foundation, with encouraging signs of delivering context-sensitive governance insights while reducing potential hallucinations through a structured analytical approach. As governance standards and regulatory expectations evolve, the system's modular and flexible architecture is designed to accommodate new requirements and scale to meet future governance challenges.

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