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CHALLENGES IN INSURING AGAINST CATASTROPHIC RISKS

Jelena Kočović
Faculty of Economics and Business, University of Belgrade, Serbia
jelena.kocovic@ekof.bg.ac.rs
ORCID: 0000-0003-3219-4746

Nataša Tešić
Faculty of Business Economics Bijeljina, University of East Sarajevo, Republic of Srpska, BiH
natasa.tesic@fpe.ues.rs.ba
ORCID: 0000-0002-3140-4919

Marija Koprivica
Faculty of Economics and Business, University of Belgrade, Serbia
marija.koprivica@ekof.bg.ac.rs
ORCID: 0000-0003-4239-2252

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Abstract: *This paper addresses the key challenges in insuring against catastrophic risks, with a particular focus on flood risk as one of the most complex and economically significant natural hazards in contemporary conditions. These challenges stem from the increasing frequency and severity of extreme events, the spatial and temporal correlation of losses, high loss severity, as well as methodological difficulties in risk measurement and persistent institutional and market constraints reflected in the protection gap between economic and insured losses. The paper examines the extent to which different flood insurance models can contribute to addressing these challenges. The findings indicate that no single institutional model provides a universally optimal solution. While public models improve accessibility and social protection, and private models enhance risk-based pricing and efficiency, both exhibit significant limitations when applied in isolation. Public–private arrangements, when supported by robust risk assessment and a clear allocation of responsibilities, offer the greatest potential to reduce the protection gap and ensure more sustainable, resilient financial protection against flood losses.*

Key words: *catastrophic risks, flood risk, insurance, risk measurement, climate change, public-private model*

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1. INTRODUCTION

Catastrophic risks are gaining increasing economic, social, and developmental significance in contemporary conditions, driven by the rising frequency and intensity of extreme natural events, the growing concentration of population and assets in exposed areas, and the pronounced protection gap between total economic and insured losses. Within this group of risks, floods occupy a particularly important position, both in terms of their frequency and the scale of their consequences, as they simultaneously affect human lives, infrastructure, productive capacities, and public finances. In such circumstances, insurance plays a crucial role as a financial risk management instrument. However, its effectiveness depends on the extent to which risks can be accurately measured and on the existence of an institutional framework capable of providing accessible, sustainable, and long-term protection.

Against this background, the paper addresses the key challenges in insuring against catastrophic risks, with a particular focus on flood risk as one of the most widespread and financially significant forms of natural hazards. The aim of the paper is to assess the extent to which different flood insurance models can contribute to mitigating these

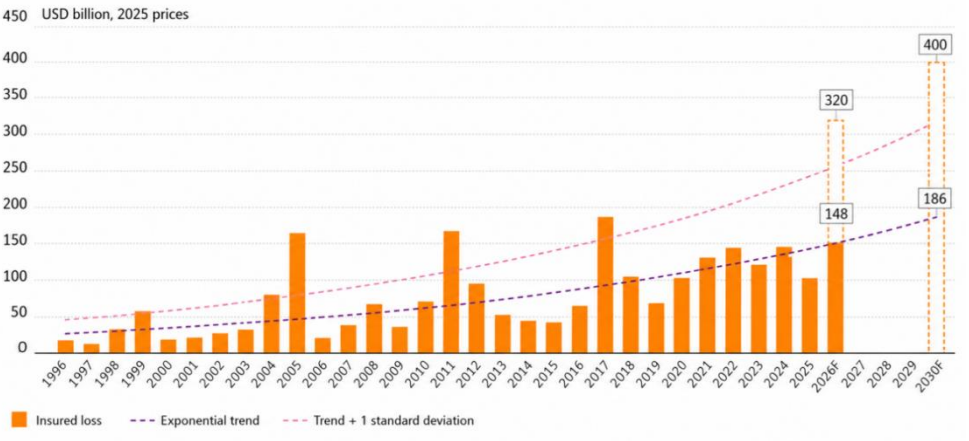
challenges. The paper is organised into three sections. The first section examines the impact of climate change and natural disasters over the past decade, with particular emphasis on the growing importance of hydro-meteorological events. The second section analyses approaches to measuring flood risk as a necessary basis for loss estimation, premium setting, and risk management. The third section reviews the main models of flood risk insurance, public, private, and public–private, highlighting their advantages, limitations, and conditions for effective implementation. The underlying premise of the paper is that the challenges in insuring against catastrophic risks arise not only from changes in the nature of hazards themselves, but also from methodological difficulties in their measurement and institutional constraints in the organisation of effective financial protection.

2. CLIMATE CHANGE AND NATURAL DISASTERS OVER THE PAST DECADE

Over the past decade, natural disasters have had significant consequences for human lives, the economy, and the environment, with climate change further amplifying the frequency and intensity of hydro-meteorological events in particular. According to the report by the Copernicus Climate Change Service (C3S) and the World Meteorological Organization (WMO) (2025), 2024 was the warmest year since the beginning of instrumental records, while the period from 2015 to 2024 comprises the ten warmest years on record. These trends confirm that climate change is not merely a long-term threat but also a factor already influencing the dynamics of natural hazards and increasing the exposure of populations, infrastructure, and economic activities. When climatic threats interact with social and economic vulnerabilities, even relatively common natural hazards can escalate into large-scale disasters, leaving behind substantial material damage, loss of life, and long-term consequences for the living conditions of millions of people worldwide (Tešić, 2025).

The consequences of these changes are particularly evident in the growing significance of hydro-meteorological events, including storms, extreme precipitation, and floods. In Europe, which is warming faster than other continents, 2024 was the warmest year on record, while floods were the most widespread since 2013, resulting in at least 335 fatalities and affecting approximately 413,000 people (C3S & WMO, 2025). At the global level, EM-DAT recorded 393 natural disasters in 2024, causing 16,753 deaths, affecting 167.2 million people, and generating nearly USD 242 billion in economic losses (CRED, 2025). At the same time, the Swiss Re Institute indicates that insured losses from natural catastrophes remained above USD 100 billion in 2025, with increasing importance attributed to so-called secondary perils, including floods and severe storms (Swiss Re Institute, 2026).

Chart 1. Global Insured Losses from Natural Catastrophes: Trends and Projections



Source: *Swiss Re Institute. (2026). Natural catastrophes in 2025: The persistent rise of wildfire and storm risk (sigma No. 1/2026). Swiss Re.*

Chart 1 illustrates that insured losses from natural catastrophes, despite pronounced year-to-year fluctuations, follow a clear long-term upward trend. Although the 2025 value remained below the long-term trend, this does not indicate a reduction in risk. Rather, it reflects the inherent volatility of catastrophic events and the absence of a major primary peril in that year. According to estimates by the Swiss Re Institute, if current trends continue, insured losses could reach approximately USD 148 billion in 2026 and USD 186 billion by 2030, while in a severe loss year

scenario, they could increase to around USD 320 billion (Swiss Re Institute, 2026). This confirms that contemporary challenges in insuring against catastrophic risks arise not only from the increasing frequency of extreme events but also from the growing concentration of exposures, the increasingly complex financial dynamics of catastrophic losses, and the need to ensure adequate financial protection amid intensifying risks and a pronounced protection gap.

In such an environment, floods are the most widespread type of natural disaster in the contemporary world. According to UNDRR data, they account for approximately 35–40% of weather-related disasters, while the number of recorded flood events has increased by 134% since 2000 compared to the previous two decades (UNDRR, 2025). Available estimates indicate that nearly 19% of the global population is exposed to some form of flood risk (Salhab & Rentschler, 2020), while global data confirm that floods account for about 44% of all recorded natural disasters, with landslides - classified within the same hydrological category - representing an additional 5% (UNDRR & CRED, 2020). Moreover, over the past decade, floods have been responsible for more than one-third of all disaster-related fatalities and, due to their frequency and spatial extent, have generated economic losses comparable to those caused by earthquakes or severe tropical cyclones (Swiss Re Institute, 2023).

These indicators confirm that flood risk management cannot be based solely on post-disaster recovery, but must also encompass more precise measurement, forecasting, and financial absorption of risk. Therefore, examining the possibilities for measuring flood risk represents a key prerequisite for selecting a sustainable insurance model.

3. POSSIBILITIES FOR MEASURING FLOOD RISK

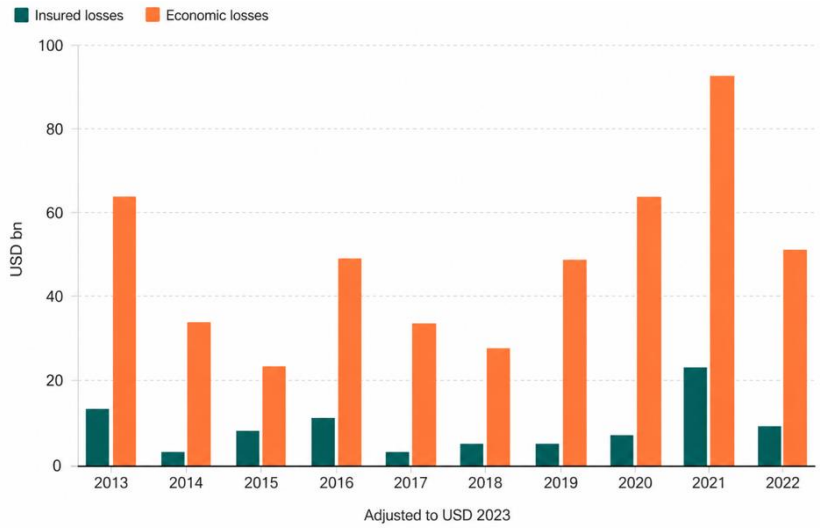
From an insurance perspective, the key issue extends beyond identifying flood hazards to the reliable assessment of both the probability and severity of potential losses. Without such an assessment, it is not possible to adequately price premiums, limit risk accumulation, or design an appropriate system of reinsurance and public support. Unlike frequent, low-severity losses - where non-life insurance can rely on more stable historical experience - floods are characterised by pronounced spatial concentration and temporal simultaneity of losses, along with the potential for very high damages. Consequently, flood risk requires more sophisticated analytical approaches than those applied to standard high-frequency risks.

In the academic literature and international practice, flood risk is most commonly viewed as the result of the interaction between hazard, exposure, and vulnerability, with some approaches treating response and recovery capacity as a separate component, while others consider it an integral part of the broader concept of vulnerability (de Moel et al., 2015; Merz et al., 2010; UNISDR, 2017). Such an approach is based on the premise that a severe hazard does not necessarily lead to catastrophic outcomes if exposure and vulnerability are relatively low, whereas the most severe impacts arise when flood hazards coincide with a high concentration of population, assets, and infrastructure, combined with pronounced vulnerability of the affected area (Tešić, 2025). This implies that, in addition to the probability of flooding, it is necessary to assess the scale of exposed assets and population, as well as their sensitivity to different water depths, duration, and flow velocity. In practice, flood risk is measured by combining historical data, hydrological and hydraulic models, geographic information systems, satellite observations, and hazard and risk maps. Based on such assessments, it is possible to derive indicators such as the expected annual loss and loss exceedance probability curves, which are of particular importance for insurance, reinsurance, and capital management. The severity of flood risk is further illustrated in Chart 2, which, using a specific example of flood-related losses, demonstrates what has already been observed for catastrophic risks more broadly, i.e. a significant gap between total economic and insured losses. In other words, the chart confirms that a substantial portion of the financial consequences of floods remains outside the scope of insurance coverage. This pattern is particularly pronounced in countries with lower insurance penetration, but it is not negligible even in developed economies, where floods increasingly exceed the capacity of existing infrastructure and traditional risk assessment models (Tešić, 2025). An additional challenge is that climate change and urbanisation are reducing the reliability of statistical estimates, which is why contemporary approaches increasingly incorporate climate scenarios and early warning systems.

In this context, an additional methodological challenge for insurance is that historical flood data are often limited, heterogeneous, and insufficient to reliably assess rare but devastating events. Consequently, stochastic models and Monte Carlo simulations are increasingly applied in contemporary practice, while Bayesian approaches are used in situations of scarce or incomplete data to estimate loss distributions and quantify uncertainty (Paudel et al., 2013; Shahi et al., 2025). On this basis, loss exceedance probability curves are constructed, enabling a more precise

assessment of the likelihood of extreme losses and having direct applications in premium setting, risk accumulation management, reinsurance design, and capital requirement assessment. In addition, stochastic scenarios allow for stress-testing portfolios under various assumptions-such as climate change, urbanisation, and increasing exposure-thereby further enhancing the understanding of the uncertainty inherent in flood risk.

Chart 2. Global Economic and Insured Flood Losses, 2013-2022 (in USD billions, adjusted to 2023 prices)



Source: *Swiss Re. (2023). Natural catastrophes in focus: Floods. https://www.swissre.com/risk-knowledge/mitigating-climate-risk/floods.html.*

Without such estimates, insurance premiums may be insufficient to cover the assumed risk or excessively high, thereby simultaneously undermining insurers' solvency and the affordability of insurance coverage. It follows that more accurate measurement of flood risk constitutes a necessary foundation for designing appropriate financial protection mechanisms, but is not sufficient in itself in the absence of an institutional and market framework capable of absorbing and distributing such risk. For this reason, the issue of risk measurement naturally leads to the question of selecting an appropriate insurance model, that is, the manner in which the financial burden of flood losses is allocated among the state, the private sector, and policyholders.

4. FLOOD INSURANCE MODELS

Insurance is one of the key instruments for transferring flood-related financial risk, particularly in countries with developed markets and strong institutional capacity. Once a portion of expected losses is reduced through risk identification, assessment, and mitigation measures, the remaining, residual risk can be managed through insurance, which spreads losses over time and across a large pool of participants, alleviates fiscal pressure, and facilitates faster recovery following a catastrophic event (Pollner, 2001). However, flood risk differs significantly from standard insurable events, as it is characterised by spatially and temporally correlated losses, high loss severity, low frequency, and pronounced uncertainty. As a result, flood protection is not organised uniformly in practice, but rather through various institutional models that differ in the degree of state involvement, the role of the private sector, and the allocation of the financial burden of losses (Kočović et al., 2018). In this context, public, private, and public–private models of flood risk insurance can be distinguished.

The **public model of flood risk insurance** refers to an institutional arrangement in which the state plays a central role in organising and financing protection against flood-related losses. In practice, such an approach is most commonly implemented through dedicated funds, public insurers, or government programmes that provide relatively standardised coverage for flood risks of particular relevance to a given country (Kočović et al., 2018). Its main advantage lies in the fact that, owing to its fiscal capacity and ability to borrow, the state can assume a portion of the risk that the private market cannot cover at sustainable prices, especially in the context of large-scale and spatially concentrated losses (Cummins & Mahul, 2009).

Illustrative examples of such arrangements show that public models, or models with a dominant public role, are most commonly developed where the private market cannot independently provide widely accessible and affordable flood risk coverage. One of the most well-known examples is the *National Flood Insurance Program* (NFIP) in the United States, established in 1968, under which the risk is primarily borne by the federal programme, while private insurers participate in the sale and administration of policies without assuming the underlying risk (Michel-Kerjan, 2010; Grigg, 2019). A similar example of a dominant public role exists in Spain, where the *Consorcio de Compensación de Seguros* provides coverage for so-called extraordinary risks, including floods, and is financed through a compulsory surcharge on premiums attached to certain private insurance policies (Paudel, 2012). By contrast, the experience of Hungary shows that the mere establishment of a publicly organised pool is insufficient to achieve the expected level of insurance penetration without appropriate political support and institutional mechanisms for implementation (Linnerooth-Bayer et al., 2005).

The particular importance of the public model becomes evident when it is necessary to ensure broad population coverage and to mitigate problems of adverse selection and voluntary underinsurance. This is often achieved through the mandatory or automatic inclusion of flood protection within certain types of property insurance policies, combined with the possibility of premium subsidies for socially or geographically vulnerable groups (OECD, 2026). In this way, the public model functions not only as a compensation mechanism but also as an instrument of social stability and fiscal protection, reducing the need for ad hoc budgetary assistance following catastrophic events.

At the same time, public programmes can also have a preventive function if their operation is based on compliance with building standards, flood protection measures, and appropriate land-use practices (Cummins & Mahul, 2009). However, this model also entails significant limitations. When premiums are maintained at politically acceptable levels rather than reflecting the actual level of risk, public programmes may become financially unsustainable and dependent on budgetary support or additional borrowing following major flood events (McAneney et al., 2016). Moreover, premiums that do not reflect the true level of risk can weaken price signals, lead to inefficient resource allocation, and reduce incentives for preventive action in high-risk areas (Cummins & Mahul, 2009). The public model can be particularly important where the private market is unable to independently provide adequate flood protection, but its long-term effectiveness depends on an appropriate balance among social objectives, fiscal sustainability, and incentives for risk reduction.

The limitations of the public model highlight that broad access to flood protection does not necessarily go hand in hand with market efficiency and pricing discipline. For this reason, the private insurance model emerges as an alternative institutional approach, shifting the focus of protection from state fiscal support to market-based risk pricing and allocation.

The **private model of flood risk insurance** is based on the premise that the primary responsibility for risk assessment, underwriting, and risk transfer is borne by commercial insurers and reinsurers, while the role of the state is largely limited to the regulatory framework and, where necessary, support measures for particularly vulnerable groups. In such an approach, insurance is organised on a voluntary and market-based basis, with premiums determined in line with the assessed level of risk, and the sustainability of the system depending on the ability of the private sector to secure sufficient capital, ensure adequate diversification, and allocate losses efficiently (Paudel, 2012).

The main advantage of the private model lies in its ability to promote more accurate risk pricing, differentiate premiums according to the level of exposure and vulnerability, and develop more innovative products and more efficient claims management procedures. In this way, market-based insurance sends clear price signals regarding the actual level of risk, encouraging policyholders to invest in preventive measures, adopt more appropriate land-use practices, and enhance the resilience of their properties. An additional advantage is that the financial burden of flood losses is transferred to a greater extent from the state to insurers, reinsurers, and risk bearers, thereby alleviating the immediate pressure on public finances (Cummins & Mahul, 2009; Sheehan et al., 2023).

However, in the case of floods, the private model faces significant limitations. Due to the spatial and temporal correlation of losses, the potential for very large losses, and the presence of heavy-tailed loss distributions, private insurers must hold substantial capital, thereby increasing the cost of coverage and limiting its affordability (Kousky & Cooke, 2009). At the same time, high premiums and the voluntary nature of insurance uptake further hinder broader insurance penetration, particularly in high-risk areas. Under such conditions, the private market often fails to provide

widely accessible coverage, leaving a significant share of losses uninsured (Perazzini et al., 2022). Therefore, although the private model is important from the perspective of market discipline and pricing efficiency, in practice it rarely constitutes a sufficient solution on its own.

The limitations of the private model demonstrate that market discipline and pricing efficiency, while important, are often insufficient on their own to ensure broadly accessible and financially sustainable flood protection. When premium levels become a barrier to wider insurance penetration and potential losses exceed the capacity of the private sector, public intervention is no longer an exception but a necessary condition for system stability. Accordingly, a third approach to organising flood protection has emerged the public-private model which seeks to combine the advantages of market-based risk pricing with the institutional and financial support of the state.

The **public–private model of flood risk insurance** is based on the sharing of responsibilities between the state and the private sector, aiming to overcome the limitations of both purely public and purely market-based solutions. In such an arrangement, the state typically provides the institutional framework, regulatory support, and financial backing for the highest layers of catastrophic losses, while private insurers and reinsurers undertake risk assessment, policy distribution, premium collection, and claims management (Paudel, 2012). The essence of this model lies in combining the state's fiscal capacity and stabilising role with the market discipline, operational efficiency, and technical expertise of the private sector. In this sense, the public–private model of flood risk insurance can also be viewed as a form of hybrid public good, as its sustainability depends not only on market exchange, but also on collective action, institutional coordination, and the continued involvement of the public sector, given that market mechanisms alone cannot ensure affordable and long-term sustainable protection against catastrophic flood losses (Barry, 2025).

The main advantage of the public–private model lies in its ability to simultaneously enhance the accessibility of insurance, ensure more stable financing of large losses, and improve the allocation of risk among different stakeholders. Compared to a purely private approach, this model allows the most extreme losses to be covered with state support, thereby reducing the likelihood of insurer withdrawal from the market and abrupt premium increases following major flood events. At the same time, the involvement of the private sector contributes to more efficient policy distribution, more accurate risk assessment, and faster claims settlement, while the public sector provides additional stability through reinsurance and fiscal support. The Cat-Nat system in France demonstrates that such an arrangement can combine the principles of national solidarity, broad population coverage, and rapid compensation by relying on the existing network of private insurers and a state guarantee for the highest layers of risk (de Marcellis-Warin & Michel-Kerjan, 2001). In this way, public-private arrangements can help reduce the protection gap and achieve a more balanced relationship between coverage affordability and the financial sustainability of the system (Perazzini et al., 2022).

However, the effectiveness of such a model depends on a clear allocation of responsibilities, a transparent financial framework, and carefully designed incentives. If the state assumes an excessive share of the burden without adequate premium differentiation and without linking insurance to prevention measures, the public–private model may lose market discipline and evolve into implicit fiscal subsidisation of high-risk areas. Conversely, when public support is primarily used to cover the highest layers of risk, while the private sector retains a central role in risk assessment, distribution, and claims management, it is possible to achieve a more sustainable and resilient system of flood protection (McAneney et al., 2016; Paudel, 2012).

CONCLUSION

In the context of climate change and increasing exposure of populations, infrastructure, and economic activities, catastrophic risks are becoming increasingly complex and economically significant. Their growing importance is reflected not only in the rising frequency and severity of extreme events, but also in the methodological difficulties of risk measurement, the spatial and temporal correlation of losses, high loss severity, and persistent institutional and market constraints, particularly visible through the protection gap between economic and insured losses.

Floods represent one of the most complex and economically significant forms of catastrophic risk. As systemic events, they can affect large geographical areas simultaneously and are among the most frequent natural hazards. Under such conditions, effective flood risk management cannot rely solely on post-disaster recovery, but requires improved risk measurement, more accurate forecasting, and timely financial absorption of losses.

The analysis highlights that the sustainability of flood insurance largely depends on the quality of hazard, exposure, and vulnerability assessments, as well as on the application of advanced analytical

approaches capable of capturing rare but severe events. Historical data, hydrological and hydraulic models, hazard and risk maps, and stochastic simulations constitute a critical basis for premium setting, risk accumulation management, and reinsurance design. Without such assessments, insurance coverage may become either financially unsustainable for insurers or inaccessible to policyholders.

The comparison of institutional models indicates that neither purely public nor purely private approaches provide a universally optimal solution. Public models enhance accessibility and social protection but are exposed to fiscal sustainability risks and weakened price signals. Private models promote market discipline and risk-based pricing but often fail to ensure affordable and widespread coverage in high-risk areas. Against this background, public–private arrangements emerge as the most balanced institutional response, combining the fiscal capacity and stabilising role of the state with the technical expertise and operational efficiency of the private sector. Such arrangements offer the greatest potential for reducing the protection gap, strengthening resilience, and establishing a more sustainable system of financial protection against flood losses.

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