Review

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The Feasibility of Parametric Insurance in Slovenia and Croatia: Lessons from Recent Disasters and Regulatory Considerations

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Abstract: This article examines the feasibility of introducing parametric insurance in Slovenia and Croatia, two European Union member states that are increasingly vulnerable to natural disasters, including floods and earthquakes. Parametric insurance, which delivers predefined payouts based on objective triggers rather than post-event loss assessments, is assessed as a potential complement to existing disaster risk financing mechanisms. Through a comparative analysis of international practices, spanning both mature insurance markets and pilot projects in developing countries, the study identifies key legal, institutional, and technical prerequisites for successful adoption. Findings indicate that neither Slovenia nor Croatia currently has a dedicated legal framework for parametric contracts, and both countries face challenges related to data infrastructure, trigger calibration, and stakeholder awareness. However, limited pilot schemes in sectors with quantifiable and time-sensitive risks appear feasible. Essential preconditions include regulatory clarity, investment in real-time monitoring systems, and alignment with evolving EU standards, including those related to digital and AI technologies. The study concludes that parametric insurance should not replace conventional coverage but may serve as a valuable supplementary tool where traditional models prove insufficient. Its phased and evidence-based introduction, supported by public–private partnerships, could strengthen national resilience and help close existing protection gaps.

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1. Introduction

Damage and economic losses from natural disasters (NatCat) have been steadily increasing, driven by factors such as urban growth, the concentration of assets in high-risk areas, and the intensification of climate change impacts. Population growth in vulnerable areas, inadequate infrastructure, and intensified weather patterns exacerbate this problem (Banerjee et al., 2024, p. 21). Additionally, insurers are facing mounting financial strain as disasters become more frequent and severe, testing the viability of risk pooling. Higher claim costs drive up premiums, reducing affordability and potentially resulting in diminished coverage availability or insurer withdrawal (International Association of Insurance Supervisors, 2024, p. 66).

This global dynamic is evident in Slovenia and Croatia. In August 2023, Slovenia suffered its most severe flooding to date, with total damages estimated at approximately EUR 3 billion. By July 24, 2024, the Slovenian government had allocated EUR 805 million for recovery efforts (Vlada Republike Slovenije, 2024). Insurance companies contributed EUR 335 million in claims payments for natural disasters in 2023, of which EUR 150 million was allocated specifically for the August floods (RTV SLO, 2024). Following the final damage assessment, a five-year reconstruction plan was adopted, allocating EUR 2.33 billion for key sectors, including water infrastructure, municipal infrastructure, landslide remediation, restoration of residential and commercial properties,

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replacement housing, preservation of cultural heritage, and protection of natural areas. Specifically, EUR 1.36 billion was allocated for watercourses. Additionally, EUR 824 million was allocated for national roads and railways, EUR 230 million for economic recovery, and EUR 5 million for primary agricultural production, fisheries, and aquaculture (Vlada Republike Slovenije, 2024).

In Croatia, the earthquakes that struck Zagreb and Petrinja in 2020 caused some of the country's most devastating losses. These earthquakes caused total damages exceeding EUR 16.1 billion, with projected reconstruction costs surpassing EUR 25.9 billion. The total damage in Zagreb was estimated at EUR 11.3 billion, with reconstruction costs expected to exceed EUR 17.5 billion. Insurance companies covered only HRK 400–500 million (approximately EUR 53.08–66.42 million, based on the fixed exchange rate set by the European Central Bank [ECB], 2022, which will also be used throughout the article for currency conversion for the year 2022) of claims for the Zagreb earthquake, while the total estimated losses amounted to HRK 86 billion (approximately EUR 11.41 billion) (Uroš et al., 2024, pp. 240–241; Novac.jutarnji.hr, 2020).

Compared to Zagreb, the Petrinja earthquake caused an estimated economic loss of EUR 4.8 billion, with recovery and reconstruction needs projected at EUR 8.4 billion. By September 2020, insurers had disbursed nearly HRK 200 million (approximately EUR 26.54 million, based on the fixed exchange rate set by the ECB in 2022), settling over 6,000 claims. Despite these efforts, a significant insurance coverage gap remained, prompting the government to provide HRK 120 million (approximately EUR 15.93 million, based on the fixed exchange rate set by the ECB, 2022) in immediate aid and HRK 101.5 million (approximately EUR 13.48 million, based on the fixed exchange rate set by the ECB, 2022) in donations to support housing and reconstruction (Uroš et al., 2024, pp. 240–241; Vlada Republike Hrvatske, 2020; Vlada Republike Hrvatske, 2021; Tportal.hr, 2020).

Recent flood events in northern Croatia (August 2023) and Podgora (October 2024, with 140 litres of rainfall per square meter) have further revealed deficiencies in flood defences and emergency response systems, emphasising the need for proactive risk management solutions (dnevnik.hr, 2024; tportal.hr, 2024; n1info.rs, 2024). In response, Croatia announced a EUR 2 billion investment plan for flood protection and water management by 2030, with EUR 1.6 billion allocated to flood defence across 294 new projects aimed at mitigating flood risks. The most significant investments include EUR 227 million for the Karlovac area, EUR 16 million for Ogulin, and EUR 73.5 million for saltwater intrusion protection in the Neretva region. Given the increasing frequency of torrential floods, 129 additional projects are planned, including 77 in the Upper Sava area, along with measures such as regulating torrents in Podgora, protecting Požega from flash floods, and improving the Sukošan stream and its tributary, Debeljak. Furthermore, EUR 400 million is earmarked for public irrigation projects to enhance agricultural resilience (Brnić, 2024).

While both countries have implemented large-scale recovery programs, notable gaps remain in prevention, insurance coverage, and timely response. Internationally, parametric insurance has emerged as a potentially useful mechanism to supplement traditional models, especially in countries with data constraints or exposed to rapid-onset events.

Parametric insurance is a type of coverage that provides payouts based on predefined, measurable parameters rather than reimbursing actual losses. Unlike traditional indemnity-based insurance, which requires extensive documentation and post-event loss assessments, parametric insurance simplifies claims using objective triggers, such as wind speed, rainfall levels, or seismic activity, to determine payouts. Once the threshold is met, compensation is automatically disbursed, reducing administrative complexity and accelerating fund disbursement (Lopez & Thomas, 2023, p. 2; Cohn et al., 2017, p. 294). This approach lowers transaction costs and enhances efficiency by eliminating the need for individualised assessments (Cohn et al., 2017, p. 294).

This article explores the potential of parametric insurance as a complementary risk transfer solution. The purpose is to assess whether and how this model could enhance resilience, reduce protection gaps, and improve financial stability in Slovenia and Croatia. It reviews global and regional practices, examines relevant regulatory and infrastructural conditions, and proposes a phased approach based on legal, institutional, and technical feasibility. By drawing on comparative

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case studies and aligning with the evolving EU legislative framework, the analysis aims to contribute to policy and academic debate on innovative insurance solutions for climate and disaster risks.

2. Materials and Methods

This article adopts a qualitative and review-based methodology. It analyses the feasibility of introducing parametric insurance in Slovenia and Croatia by systematically examining recent catastrophic events, legal frameworks, international practices, and technological developments. The analysis is structured around four interrelated components.

First, the study synthesises publicly available data on natural disasters and insurance payouts in Slovenia and Croatia, with a particular focus on the 2020 earthquakes and the 2023 floods. These cases serve to illustrate the extent of uninsured losses and the fiscal burden on governments.

Second, it provides an overview of selected international examples of parametric insurance, as discussed in the literature and policy reports. These serve as a basis for identifying standard features, benefits, and limitations relevant to the regional context.

Third, the article examines regulatory and legal aspects relevant to the implementation of parametric insurance. It identifies potential challenges related to contract enforceability, claims procedures, and consumer protection within the Slovenian and Croatian legal systems.

Fourth, it explores the potential integration of smart contracts and blockchain technology in parametric insurance. Based on secondary sources, it evaluates their suitability for automating payouts and enhancing transparency, while also acknowledging legal uncertainties, particularly about data protection and dispute resolution.

This study does not involve original empirical research, primary data collection, statistical modelling, or access to confidential datasets. It relies exclusively on secondary sources, including legal texts, policy documents, academic literature, and official statistics, to conduct a systematic and interdisciplinary review. No new data, computer code, or experimental protocols were created.

3. Insurance Gaps and Economic Losses from Natural Catastrophes

According to Cousaert et al. (2022), the global insurance industry generated approximately 6 trillion USD in premiums, exceeding the total economy of countries such as Germany and Japan (Cousaert et al., 2022, p. 238).

The top 10 countries with the highest insurance coverage rates are: the United States (82.5% coverage, 274.2 million insured out of 332.4 million), Japan (95.9%, 120.5 million insured out of 125.5 million), Germany (95.5%, 79.7 million insured out of 83.2 million), and France (96.6%, 65.2 million insured out of 67.2 million). Other high-coverage countries include Canada, the United Kingdom, Italy, and Spain, with rates ranging from 95.2% in the UK to 96.8% in Spain. Australia has a coverage rate of 97.3%, ensuring protection for 25.0 million residents out of a total population of 25.7 million. (Custom Market Insights, n.d.).

In 2023, natural disasters led to a significant increase in non-life insurance claims across various regions. Major events included severe flooding in central Greece, a hurricane in Mexico, a landslide and storm in Norway, storms and floods in Slovenia, an earthquake in Türkiye, and a drought in Uruguay, which led to a surge in claims payments (OECD, 2024, p. 21).

Global economic losses from natural catastrophes in 2023 reached USD 280 billion (Banerjee et al., 2024, p. 2), equivalent to approximately EUR 258.95 billion, using the 2023 average exchange rate of 1 USD = 0.9248 EUR (Banka Slovenije, 2023). Of these losses, approximately 62% were uninsured (Market.us, 2024; Swiss Re, 2024).

Munich Re (2025) reported global economic losses from natural disasters in 2023 at USD 268 billion (EUR 247.85 billion), adjusted for inflation. Of these, USD 106 billion (EUR 98.03 billion) were insured, leaving an estimated 60% of the losses (USD 162 billion / EUR 149.82 billion) uninsured. Similarly, Market.us (2024) estimated that over 400 major natural disasters occurred in 2023, resulting in total economic losses of USD 380 billion (EUR 351.43 billion), with 69% of the losses uninsured.

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In 2024, global economic losses from natural disasters increased to USD 320 billion (EUR 295.55 billion), based on the 2024 average exchange rate of 1 USD = 0.9236 EUR (Banka Slovenije, 2024). Of these losses, 56% were uninsured. The year ranked as the third most expensive for insured losses and the fifth most expensive for total economic losses since 1980 (Munich Re, 2025).

Aon (2025) reported even higher figures, estimating total economic losses from natural disasters in 2024 at USD 368 billion (EUR 339.88 billion). The primary contributors were Hurricanes Milton and Helene, as well as severe convective storms in the U.S., and widespread flooding across Europe (Aon, 2025).

In December 2024, the European Central Bank (ECB) and the European Insurance and Occupational Pensions Authority (EIOPA) proposed an EU-level approach to reducing the economic impact of natural disasters. The proposal includes a two-pillar solution: (1) a public-private reinsurance scheme to pool risks across the EU, increasing insurance coverage, and (2) an EU disaster relief fund to support infrastructure recovery, contingent on prior risk mitigation measures. The initiative aims to address the growing financial risks of climate change and close the insurance protection gap (ECB, 2024).

These figures highlight the persistent protection gap and the need to consider alternative risk financing mechanisms. In Slovenia and Croatia, traditional indemnity-based insurance has not fully addressed the financial consequences of recent natural disasters. Under certain conditions, parametric insurance may represent a faster and more transparent supplementary instrument. Its inclusion in national disaster risk management frameworks could, where appropriate, support financial preparedness and limit reliance on post-disaster public funding.

4. From Potential to Implementation: Operational Benefits and Constraints of Parametric Insurance

Cousaert et al. (2022) emphasise that the insurance industry must continually evolve to address emerging risks from new technologies, the increasing frequency of natural disasters, shifting consumer demands for customised and transparent services, and advancements in insurance fraud techniques. To meet these challenges, flexible policy design, efficient data management, and transparent insurance processes are essential (Cousaert et al., 2022, p. 238).

The applications of parametric insurance span multiple sectors. In agriculture, policies can be tailored to address rainfall deficiencies, while in energy markets, payouts may be triggered by deviations in wind speed or temperature. In the tourism industry, parametric insurance has been utilised to cover losses resulting from catastrophic events such as hurricanes (Radu & Alexandru, 2022, p. 1; Hao et al., 2023, p. 1). Furthermore, its role in supporting climate adaptation is becoming increasingly significant, providing financial security to seafood producers facing climate-induced risks while enabling a transition to sustainable practices (Hobday et al., 2025, p. 1). Beyond physical sectors, parametric models are also expanding into digital domains. The development of parametric covers in cyber insurance, based on objective IT security indicators, underscores the broader applicability of parametric models to emerging digital risks as well (Dal Moro, 2020, pp. 1–2, 5).

While parametric insurance offers numerous benefits, it also presents significant challenges. One of its primary objectives is to narrow the protection gap, the disparity between total economic losses from disasters and the portion of these losses covered by insurance. This gap is vast in vulnerable regions, where insurance coverage is low, and many losses remain uninsured. Parametric insurance can help strengthen financial resilience by providing faster payouts and reducing reliance on post-disaster aid. (Sandland et al., 2019, p. 89; Lin & Kwon, 2020, pp. 13–14).

Biffis et al. (2021) argue that parametric insurance can help smallholder farmers access credit by acting as a substitute for collateral, as demonstrated in pilot programs in Tanzania. Reducing collateral constraints supports financial inclusion, enabling farmers to invest in more productive agricultural inputs. However, its effectiveness is limited by basis risk, where payouts may not align with actual losses, and ambiguity aversion, which makes farmers hesitant to trust the insurance mechanism. (Biffis et al., 2021, p. 3). Another challenge is that poorly structured parametric policies

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can create unintended consequences, such as encouraging over-reliance on payouts instead of promoting proactive risk adaptation (Hobday et al., 2025, p. 3).

While parametric insurance is much faster and more efficient, it cannot fully replace traditional insurance, which covers the actual extent of financial losses. Instead, parametric insurance best complements traditional policies, helping simplify processes, reduce administrative work, and improve economic stability (Broberg, 2019, pp. 700–701). In addition to standard parametric policies, parametric catastrophe bonds have emerged as an innovative mechanism for transferring the financial risks of natural disasters to capital markets, offering rapid payouts and enhancing overall risk-bearing capacity (Tavanaie Marvi & Linders, 2021, pp. 1–2, 9).

Moreover, the increasing integration of AI and digitalisation in the global insurance sector must be considered, as these technologies offer significant advantages but also introduce challenges to regulatory and financial stability. The widespread adoption of AI presents both external and internal risks for insurers, which continue to evolve in tandem with advancements in AI technology and the implementation of risk mitigation strategies (International Association of Insurance Supervisors, 2024, p. 23).

For Slovenia and Croatia, parametric insurance may contribute to more effective disaster response by facilitating quicker payouts, streamlining administrative procedures, and potentially supporting a gradual transition toward more preventive and data-informed risk management approaches.

5. Global and Regional Growth of Parametric Insurance Market

The parametric insurance market is experiencing significant regional growth, with different regions focusing on various risks and leveraging technology to address them. In North America, the market has benefited from utilising technology and data analytics to price risks, particularly those related to climate events such as hurricanes and wildfires. Europe has increasingly integrated parametric insurance with traditional products, with a notable focus on agriculture due to the growing risks associated with climate change. The Asia-Pacific region is witnessing rapid growth, mainly due to the frequency of natural disasters, including typhoons and earthquakes. The LAMEA region, comprising Latin America, the Middle East, and Africa, is emerging as a market for parametric insurance, addressing risks associated with natural disasters, political instability, and climate change (Market.us, 2024).

The parametric insurance market has experienced substantial growth in recent years, driven by increasing demand for innovative risk transfer solutions. According to Market Research Future and Allied Market Research reports, estimates for 2023 placed the market size between USD 13.78 billion (EUR 12.74 billion) and USD 18 billion (EUR 16.65 billion) (Allied Market Research, 2024; Gupta, 2025). Another study estimated the market at USD 15.8 billion (EUR 14.61 billion) in 2023, projecting growth to USD 40.6 billion (EUR 37.55 billion) by 2033 at a compound annual growth rate (CAGR) of 9.9%. Geographically, North America held a dominant market position in 2023, capturing more than a 35% market share with USD 5.5 billion (EUR 5.09 billion) in revenue (Market.us, 2024).

As of early 2025, the parametric insurance market was estimated to have reached between USD 14.42 billion and USD 16.68 billion in 2024, though final confirmed data were not yet publicly available (Gupta, 2025; Research Nester, 2025). An additional estimate placed the 2024 market size at USD 16.2 billion (EUR 17.54 billion) (Research & Markets, 2025).

Various studies (KBV Research, 2022; Gupta, 2025; Allied Market Research, 2024; Research Nester, 2025) indicate that the parametric insurance market is on a steady growth trajectory, with all projections consistently pointing toward expansion. While estimates vary, they all suggest significant market growth over the coming years. All historical and forecasted values in USD were converted into EUR using the 2024 average annual exchange rate (1 USD = 1.0824 EUR), as published by Banka Slovenije (Banka Slovenije, 2024).

By 2028, the parametric insurance market is projected to reach USD 21.4 billion (EUR 19.77 billion), growing at a compound annual growth rate (CAGR) of 9.6% during the forecast period (KBV

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Research, 2022). Longer-term forecasts suggest that by 2032, the market could reach USD 26.31 billion (EUR 24.31 billion) (Gupta, 2025). By 2033, it is projected to reach USD 34.4 billion (EUR 31.78 billion), representing a compound annual growth rate (CAGR) of approximately 6.6% (Allied Market Research, 2024). By 2034, it is projected to reach USD 51.3 billion (EUR 49.54 billion), rising at a CAGR of 12.60% (Research & Markets, 2025). By 2037, the market is anticipated to reach USD 70.29 billion (EUR 64.94 billion), representing an increase of USD 53.61 billion (EUR 49.53 billion) from 2024, and a compound annual growth rate (CAGR) of 11.7%. This growth is primarily attributed to advancements in data analytics, the increasing impact of climate change, and the expanding adoption of parametric insurance in industries such as agriculture, construction, and energy (Research Nester, 2025).

The continued expansion of the parametric insurance market is primarily attributed to advances in data analytics, increasing exposure to climate-related hazards, and broader sectoral adoption, including in agriculture, energy, tourism, and infrastructure. These developments may be particularly relevant for Slovenia and Croatia, where floods have become more frequent and severe in recent years, and where earthquakes have resulted in substantial economic losses. If supported by adequate data infrastructure and regulatory clarity, the integration of parametric models could offer a timelier and more transparent approach to disaster recovery and risk financing, particularly in underinsured or high-exposure areas such as selected rural and coastal regions.

6. Global Regulatory Landscape of Parametric Insurance

According to the 2023 Global Parametric Insurance Law Guide, parametric insurance is not currently addressed by specific legislation in most European countries. Instead, it falls under general insurance frameworks in Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and the United Kingdom, with no explicit legal provisions dedicated to parametric models (DLA Piper, 2023, pp. 30–60).

In Slovenia, parametric insurance contracts are regulated under the general provisions of the Obligacijski zakonik [Obligations Code], Uradni list RS, št. 83/2001 s spremembami, and the Zakon o zavarovalništvu [Insurance Act], Uradni list RS, št. 93/2015 s spremembami. Likewise, in Croatia, parametric insurance falls under the Zakon o obveznim odnosima [Obligations Act], Narodne novine, br. 35/2005 s izmjenama, and the Zakon o osiguranju [Insurance Act], Narodne novine, br. 30/2015 s izmjenama (DLA Piper, 2023, pp. 36, 57; Zavarovanje-osiguranje.eu, 2024).

In North America, parametric insurance is regulated at the state level in the United States, with varying rules depending on the jurisdiction. New York recently introduced specific regulations under its Insurance Law. Section § 1113(a)(34) defines parametric insurance as coverage for weather-related events, such as windstorms, floods, wildfires, or earthquakes, where payouts are based on the event's proximity and magnitude, as measured by a state or federal agency (New York State Senate, 2025a). Section § 3416 establishes disclosure requirements, stating that parametric insurance is not a substitute for property or flood insurance and may not be accepted by mortgagees or loss payees. It further requires that, if a parametric policy is placed through an excess line broker, the broker must provide these disclosures to the policyholder in writing (New York State Senate, 2025b). In Canada, parametric insurance is still in its early stages, with some insurers expanding their offerings, particularly in agriculture and resource-based industries that are affected by climate risks. While there is no specific legislation for parametric insurance, it is legally recognised under provincial Insurance Acts. Some insurers seek regulatory approval, and market growth is expected as climate-related risks increase (DLA Piper, 2023, pp. 68–69).

In Latin America, the regulatory environment for parametric insurance is diverse and varied. In Argentina, parametric insurance requires approval from the national regulator, Superintendencia de Seguros de la Nación (DLA Piper, 2023, p. 62). Brazil regulates parametric insurance through general frameworks, with a primary focus on agribusiness to mitigate climate-related risks. Bill No. 2597/2024 aims to enhance transparency and consumer protection; however, regulatory clarity remains a

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challenge (Superintendência de Seguros Privados [SUSEP], 2024). Chile has enacted Ley No. 21.521/2023, promoting innovation and financial inclusion in the parametric insurance market (DLA Piper, 2023, pp. 64–65; Insulaw International, 2023). In Colombia, parametric insurance is regulated under Ley 1955/2019 and Decreto 211/2020, with further advancements in 2024 through the National Development Plan and Decreto 1271/2024. These reforms align local regulations with International Financial Reporting Standard (IFRS) 17 and introduce new measurement methods to enhance financial transparency (DLA Piper, 2023, p. 66; Brigard Urrutia, 2023; Englobally Latinoamérica, 2024).

In Puerto Rico, Uganda, and Uruguay, parametric insurance is regulated under specific laws, offering more structured frameworks for using these products. However, many other countries in Latin America, such as Bolivia, Panama, Paraguay, and Venezuela, allow parametric insurance under general insurance laws but lack specific regulations (Garcia Ocampo & Lopez Moreira, 2024, p. 14).

To support the responsible and more consistent use of parametric insurance, Slovenia and Croatia could consider introducing targeted legislative provisions that define key legal concepts and clarify the regulatory status of such products. Currently, both jurisdictions regulate parametric insurance under general contract and insurance law, which may not adequately address issues specific to index-based mechanisms, such as trigger verification, payout certainty, and consumer protection. Comparative experience from jurisdictions such as the State of New York or Colombia illustrates how dedicated rules and disclosure obligations can enhance legal clarity and promote transparency. Moreover, in light of cross-border disaster risks such as floods, improved regional cooperation through harmonised terminology and data exchange protocols could contribute to legal consistency and facilitate future implementation. While the adoption of parametric insurance remains in an early phase, a more transparent regulatory framework may provide the legal certainty necessary for further development, while ensuring alignment with national risk governance objectives and emerging EU policy initiatives.

7. Smart Contracts and Their Role in Modern Risk Management

While parametric insurance can operate without blockchain or smart contracts, integrating these technologies provides significant advantages. Blockchain-enabled parametric insurance reduces operational costs by automating underwriting and claims settlement, ensuring transparent execution (Hao et al., 2023, p. 3). Smart contracts were first introduced by Szabo (1996) as digital agreements that embed contractual clauses into computer systems for automatic execution and enforcement, thereby enhancing transaction security and reducing the risk of breaches. He compared them to vending machines, which autonomously execute transactions under predefined conditions, illustrating how smart contracts embed contractual terms into digital systems to facilitate secure and self-enforcing agreements (Szabo, 1996). Smart contracts automate the claims process, minimising human errors and administrative costs while improving responsiveness, streamlining operations, and enhancing transparency and efficiency (Popovic et al., 2020, p. 3; Cohn et al., 2017, p. 290). Smart contracts are replicated across multiple nodes to prevent tampering, ensuring data integrity and security (Khan et al., 2021, p. 2902).

Blockchain technology, which functions as a decentralised and immutable ledger through consensus mechanisms, enhances parametric insurance by ensuring data integrity, transparency, and traceability (Bodemer, 2023, p. 4). Its integration with circular economy frameworks presents opportunities to develop sustainable and efficient business practices, optimise processes, and increase trust in financial transactions (Justinek, 2024, p. 5).

Smart contract-based parametric insurance benefits from integrating reliable data sources such as IoT devices and public oracles (Hao et al., 2023, p. 3). IoT technologies, including weather sensors and GPS trackers, enable real-time data collection, allowing parametric insurance to rely on publicly available, verifiable inputs rather than traditional loss assessments (Atzori et al., 2010, p. 2787; Hao et al., 2023, p. 3). Public oracles supply smart contracts with external data, such as weather forecasts

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or financial market information, ensuring transparent and automated claim verification (Beniiche, 2020, pp. 1–2; Hao et al., 2023, p. 3).

By encoding policies and payout algorithms in smart contracts, insurers eliminate manual assessments, allowing claims to be processed efficiently based on predefined conditions. Additionally, blockchain ensures that executed smart contracts remain immutable and publicly verifiable, reinforcing system reliability and reducing disputes (Hao et al., 2023, p. 3).

The emergence of smart contracts has introduced a transformative shift in contract law by replacing traditional text-based agreements with self-executing code. This innovation challenges fundamental legal principles such as offer and acceptance, consideration, and the intention to create legal relations, which form the foundation of traditional contract law (Durovic & Janssen, 2018, pp. 3, 10–17). Unlike conventional contracts, which depend on intermediaries such as courts, lawyers, and third-party enforcement mechanisms, smart contracts streamline contract execution by embedding predefined conditions directly into blockchain algorithms. This automation reduces reliance on external enforcement, expedites transactions, and lowers associated costs (Rahman, 2024, pp. 2, 3).

Another key distinction between traditional and smart contracts lies in their evidentiary value. Unlike conventional methods of proving agreements, such as witness testimony or physical documentation, smart contracts utilise cryptographic signatures and blockchain records for validation and verification purposes. This digital verification provides high security against tampering, reducing the likelihood of disputes and lowering contract enforcement costs (Cohn et al., 2017, pp. 288–290).

Despite these advantages, smart contracts raise concerns about their adaptability to the needs of contracting parties, particularly in complex contractual relationships where flexibility is essential (Nazarov, 2024, pp. 7–9). While automation increases efficiency, the lack of human discretion in contract enforcement can lead to unintended consequences. This is particularly problematic in consumer protection contexts, where fairness and transparency are critical (Maugeri, 2022, pp. 902–906).

Maydanyk (2024) argues that smart contracts must have clearly defined, objective, unambiguous, and feasible terms. These contracts should be fully automatable, meaning subjective language, such as “reasonable term,” should be avoided (Maydanyk, 2024, p. 32). Moreover, Hupe (2024) notes that smart contracts have higher upfront costs due to legal and programming expenses. However, their long-term costs are lower in complex multi-party agreements, as automation minimises the need for manual verification. While traditional contracts remain cost-effective for more straightforward transactions, smart contracts are preferable when security is the primary concern (Hupe, 2024, p. 12).

The integration of smart contracts into parametric insurance models introduces significant potential for improving efficiency, transparency, and cost-effectiveness. For Slovenia and Croatia, practical implementation would require a supportive digital infrastructure, legal recognition of code-based agreements, and safeguards to ensure fairness in automated processes. Particular attention should be given to consumer-facing applications, where the absence of human discretion could raise legal and ethical concerns. Pilot use cases with clearly defined and fully automatable terms may offer a feasible starting point, provided that regulatory frameworks evolve to accommodate the specific characteristics of smart contract execution.

7.1. Regulatory Challenges of Smart Contracts Across Jurisdictions

Despite their advantages, smart contracts also present significant challenges related to liability distribution and potential coding errors, which can lead to unintended consequences due to automatic execution (Ballaji, 2024, p. 1022). The lack of uniform regulatory frameworks complicates enforcement, particularly in cross-border transactions (Rahman, 2024, p. 5). Courts may struggle to interpret immutable, code-based agreements (Kasatkina, 2022, pp. 143–145), while scalability and security issues pose significant risks, particularly in emerging economies (Ballaji, 2024, p. 1021).

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Regulatory clarity, consumer protection, and effective dispute-resolution mechanisms remain critical to fostering the adoption of smart contracts. The decentralised nature of blockchain networks complicates jurisdictional issues as they transcend national borders, challenging the application of relevant laws (Ballaji, 2024, pp. 1025–1026). While smart contracts enhance automation and efficiency, their rigidity restricts options for redress and dispute resolution, potentially undermining consumer trust and accountability (Cutts, 2019, pp. 389–390). The complexity and diversity of smart contract ecosystems pose significant challenges to ensuring their security and reliability, particularly given the current limitations in verification tools and formal validation techniques (Kezadri Hamiaz & Driss, 2025, p. 2).

While these challenges are notable on a global scale, they are experienced differently across regions due to variations in regulatory frameworks and local conditions. In the following section, we will briefly examine how various jurisdictions approach the legal treatment of smart contracts and how this affects their implementation.

In the European Union (EU), smart contracts must comply with existing legal instruments such as the Solvency II Directive (Directive 2009/138/EC), which imposes capital requirements and governance obligations on insurers using blockchain-based solutions (Goffard & Loisel, 2024, p. 3). The directive's emphasis on risk mitigation and consumer protection highlights potential conflicts with the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679), particularly about to the right to be forgotten, which conflicts with the immutable nature of blockchain systems (Popovic et al., 2020, p. 13). Furthermore, the Consumer Credit Directive (Directive 2008/48/EC) requires pre-contractual disclosures to address information asymmetries, thereby ensuring that consumers make informed decisions (Maugeri, 2022, p. 905). The Data Act (Regulation (EU) 2023/1806) enhances consumer protection through mechanisms such as the "kill switch," allowing smart contracts to be paused or terminated in critical scenarios (Donn, 2023, p. 1047). Additionally, the Artificial Intelligence (AI) Act (Regulation (EU) 2024/1689), effective as of August 1, 2024, sets harmonised rules for the development and deployment of AI systems, including those used in smart contracts (European Parliament and Council, 2024).

The European Insurance and Occupational Pensions Authority (EIOPA) has also addressed blockchain and smart contracts in its 2021 discussion paper, advocating for a harmonised regulatory approach to mitigate supervisory challenges across member states (EIOPA, 2021, p. 27). Similarly, the European Commission's 2021 study on smart contracts and the digital single market emphasised the need for a combined legal and technological framework to ensure that smart contract innovation aligns with the principles of the Digital Single Market (Schrepel, 2021, p. 13). Although these documents are non-binding, they signal future regulatory directions that could shape the implementation of smart contracts in parametric insurance across the EU.

In the United Kingdom (UK), the UK Law Commission has affirmed the validity of smart contracts, finding that they satisfy essential elements of contract formation under English law, including agreement, consideration, and the intention to create legal relations (UK Law Commission, 2021, pp. 5, 39, 49, 54).

In the United States, various legal instruments provide recognition and enforceability for digital contracts and electronic signatures. The Uniform Commercial Code (UCC), the Uniform Electronic Transactions Act (UETA), and the Electronic Signatures in Global and National Commerce Act (ESIGN) establish a legal foundation for digital agreements, ensuring that electronic records and signatures hold the same validity as their paper-based counterparts (Cohn et al., 2017, pp. 286–289; Rahman, 2024, p. 4).

The regulatory landscape for smart contracts remains fragmented, with considerable variation across jurisdictions and ongoing tensions between legal certainty, consumer protection, and technological innovation. For Slovenia and Croatia, the key challenge lies in aligning domestic regulatory frameworks with evolving EU standards while addressing unresolved issues such as contractual rigidity, data immutability, and cross-border enforcement. The emerging EU regulatory instruments, particularly the Data Act and the AI Act, provide helpful guidance; however, their

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practical implementation will require national-level adaptation and the development of institutional capacity. Given the decentralised nature of blockchain technologies, a cautious regulatory approach that prioritises legal clarity, system interoperability, and dispute resolution mechanisms is essential for ensuring trust and long-term viability in the application of smart contracts, particularly within the insurance sector.

8. Cross-Country Applications and Lessons for Emerging Markets

The adoption of parametric insurance varies significantly across countries. Developed markets, such as Austria, France, and the United States, have implemented mature solutions, while developing countries, like Malawi, Fiji, and the Kyrgyz Republic, are primarily conducting pilot projects supported by international institutions. The following section provides a brief overview of the presence of parametric insurance providers across different regions. While this overview highlights key players and notable implementations, it does not represent an exhaustive list, as more insurers and initiatives are joining the market daily.

The key providers shaping the global parametric insurance market are believed to be Allianz Group, AXA SA, Zurich Insurance Group Ltd., Berkshire Hathaway Inc., Chubb Limited, Munich Re Group, FloodFlash Limited, Neptune Flood Incorporated, Global Parametrics Limited, and Swiss Re (Market.us, 2024).

In the European Union, parametric insurance is well-established, particularly in Austria, with a strong focus on agriculture. State-subsidised parametric drought insurance has proven beneficial, with approximately EUR 120 million in payouts following the severe 2022 drought (The Insurer, 2024).

In Belgium, insurers like Baloise offer parametric policies for adverse weather, flight delays, and baggage disruptions. These products, developed in collaboration with startups such as KASKO, Wetterheld, and Blink Parametric, provide automatic payouts triggered by predefined events, thereby eliminating the need for manual claims processing (Baloise, 2024).

In Finland, a pilot project is underway in the Boreal region to co-develop demand-driven, index-based insurance (IbI) solutions with LocalTapiola. The project examines the market potential and regulatory framework for IbI, with a focus on weather phenomena that affect crop production. The insights gained from this phase will help develop tailored parametric insurance products for farmers (PIISA Project, 2024).

France has a mature parametric insurance market. Howden France covers risks like floods and declining water levels, ensuring rapid compensation without traditional assessment delays (Howden France, 2024). Additionally, Paris-based Descartes Underwriting offers advanced solutions for climate, cyber, and emerging risks, utilising sophisticated risk modelling (Descartes Underwriting, 2024a).

Munich Re offers parametric solutions in Germany to enhance resilience against natural disasters, weather-related risks, and pandemics (Munich Re, 2024). Additionally, Descartes Underwriting has introduced parametric cyber insurance in Germany, aiming to provide businesses with faster and more transparent payouts in the event of a cyber incident (Descartes Underwriting, 2024b).

In Ireland, Blink Parametric has partnered with MAWDY InsureandGo to offer parametric insurance for flight disruptions. This solution offers global coverage to Irish travel insurance customers, providing swift and automated claims processing (Blink Parametric, 2024).

Switzerland has seen significant growth in parametric insurance despite lacking an explicit regulatory framework. Swiss Re leads the sector with solutions that target risks such as earthquakes and hurricanes, while Swiss startup Riskwolf employs AI-driven parametric solutions that leverage real-time data for emerging risks (Swiss Re, 2024; Wired, 2024).

In the UK, parametric insurance is available through several insurers. Aon offers climate risk solutions with rapid payouts (Aon, n.d.). Generali covers various industries' natural disasters and

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extreme weather (Generali, n.d.). Miller Insurance specialises in tailored parametric solutions for energy, transportation, and construction (Miller Insurance, n.d.).

Parametric insurance is also present in North America, with several providers offering solutions. Zurich North America offers weather parametric insurance to mitigate economic losses resulting from extreme weather events that can delay construction projects, even in the absence of physical damage. (Zurich North America, 2024). Munich Re US offers parametric reinsurance solutions, ensuring quick payouts based on predefined triggers (Munich Re US, n.d.). Recoop Insurance specialises in hybrid parametric disaster insurance, combining traditional and parametric coverage elements (Recoop Insurance, 2024).

In Central America, parametric insurance protects the Mesoamerican Reef (Belize, Mexico, Guatemala, Honduras, Costa Rica) and supports coastal communities. Similar programs are planned in Australia and the U.S. Allianz already offers these solutions in Colombia, Ivory Coast, Ghana, and other regions vulnerable to climate-related disasters (NATURANCE Project, 2024; Allianz, 2024).

In countries where specific legislation for parametric insurance is lacking, pilot projects are being implemented to test its viability. For example, in Malawi, parametric insurance covers districts against drought, with triggers based on the Water Requirement Satisfaction Index (WRSI), providing payouts immediately after the sowing season to prevent food insecurity and enable early intervention (United Nations Development Programme [UNDP], 2025, p. 33). In Mexico, parametric insurance has been applied to cover public health, pensions, and social security buildings, with triggers based on Peak Ground Acceleration (PGA) from earthquake maps. PGA is a measurement used to assess the intensity of seismic activity, which can trigger insurance payouts following an earthquake (UNDP, 2025, pp. 35–36). In Fiji, a pilot project has been implemented to protect coral reefs and local livelihoods in the Lau Islands, using a "gridded parametric" structure with wind speed triggers during tropical cyclones (UNDP, 2025, pp. 38–39). In the Kyrgyz Republic, a parametric insurance policy covering livestock rearing in Naryn province uses soil moisture measurements to trigger payouts during extreme droughts, benefiting over 3,200 families (UNDP, 2025, p. 41). In Vietnam, wind farms are insured against low wind periods, with historical wind data used to trigger payouts and sustain energy production (UNDP, 2025, p. 43). French Polynesia offers parametric insurance to hotels against storm surges, with payouts triggered by wave height data, enabling the tourism industry to recover quickly (UNDP, 2025, pp. 45–46). In India, informal workers are compensated for lost wages during extreme heat events, with temperature-based triggers for payouts (UNDP, 2025, pp. 48–49).

The cross-country overview highlights that the viability of parametric insurance does not depend solely on market maturity but on the presence of targeted policy support, reliable environmental data, and institutional engagement. For Slovenia and Croatia, the Austrian model of state-supported agricultural insurance demonstrates the role of public co-financing in enabling sector-specific coverage. Belgium's and Ireland's examples underscore the potential for parametric products in consumer services, particularly where real-time data enables automatic claims processing. France and Germany show how mature markets have expanded coverage to include flood risk, water levels, and cyber events, facilitated by advanced modelling. Switzerland's experience illustrates that regulatory gaps need not preclude innovation, provided there is technical capacity and insurer willingness. Meanwhile, pilot initiatives supported by UNDP, ranging from earthquake-triggered payouts in Mexico to parametric structures for tourism, energy, and informal employment, reveal the adaptability of these instruments to diverse socio-economic settings. These findings suggest that Slovenia and Croatia could initiate context-specific pilot programmes in sectors with quantifiable risks and accessible data, while gradually addressing regulatory and institutional prerequisites for broader adoption.

8.1. Persistent Challenges in Parametric Insurance Implementation

Despite the growing recognition of parametric insurance as a timely and transparent alternative to traditional indemnity models, numerous practical applications have revealed its persistent

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structural weaknesses, particularly those related to basis risk. In India, approximately 80 per cent of farmers enrolled in the Weather-Based Crop Insurance Scheme (WBCIS) expressed dissatisfaction due to the remote location of weather stations, which led to missed payouts despite actual on-site damage. Similarly, in Sri Lanka, 622 rice farmers were excluded from compensation under the weather index insurance scheme because rainfall slightly exceeded the predefined threshold, necessitating ex gratia payments. In Rwanda, one provider withdrew from a parametric program due to repeated misalignments between indexed data and actual losses. A similar issue arose in Bali, where a 2018 volcanic eruption severely impacted the tourism sector, yet no payout was triggered because ashfall levels remained below the threshold. Finally, the example of Puerto Rico after Hurricane Maria highlights the broader limitations of the insurance system. While Dominica, covered by a parametric policy, received a $19 million payout within two weeks, Puerto Rico struggled with prolonged indemnity claim disputes, leaving over $1.6 billion in claims unsettled more than two years after the event (Palwishah, Mazviona, & Sølvsten, 2023).

Moreover, recent pilot schemes in India, including SEWA's heat insurance and Nagaland's precipitation coverage, failed to trigger payouts despite severe impacts, mainly due to inadequately calibrated thresholds and insufficient data sources. These outcomes underscore the persistent gap between index design and real-world vulnerabilities, especially among climate-sensitive and low-income populations (Sirur, 2024).

Recent research has, however, shown that advanced parametric structures, such as the cat-in-a-grid trigger, can significantly reduce basis risk by over 18% in some hurricane risk models compared to traditional cat-in-a-box frameworks, which incorporate multiple geographic cells and weighted model outputs (Franco et al., 2024).

The analysis of failed or problematic implementations of parametric insurance reveals the critical importance of accurately calibrated indices, locally relevant data sources, and realistic trigger thresholds. Structural weaknesses, particularly basis risk, can severely undermine trust in parametric models, especially among vulnerable populations exposed to climate and disaster risks. For Slovenia and Croatia, these cases highlight the need for a cautious and evidence-based approach to implementation. Before broader deployment, both countries should prioritise pilot schemes with robust data infrastructure and context-sensitive design. Integrating interdisciplinary expertise and conducting impact evaluations will be essential to avoid replicating the shortcomings observed in other jurisdictions. Additionally, transparent communication with end users and safeguards for excluded or undercompensated beneficiaries should be built into any future parametric programmes.

9. Discussion, Conclusions, and Future Directions

This study examined the feasibility of introducing parametric insurance in Slovenia and Croatia. These countries are increasingly vulnerable to natural disasters, including floods (notably in Slovenia in 2023 and Croatia in 2023 and 2024) and earthquakes (notably in Croatia in 2020). Recent catastrophic events in both countries have highlighted substantial protection gaps in conventional indemnity-based insurance systems, leading to significant uninsured losses and a heavy reliance on public compensation mechanisms.

Parametric insurance, which provides payouts based on objective triggers such as rainfall levels or seismic intensity rather than loss assessments, offers potential advantages in these settings. Chief among them are faster payouts, simplified claims handling, and improved liquidity for affected sectors and public authorities. These features are particularly relevant in disaster-prone environments where traditional assessments are delayed, complex, or administratively burdensome.

Nevertheless, the analysis confirms that the adoption of parametric solutions requires more than interest or need. The success of such schemes depends on the availability of reliable and timely data, legal clarity around trigger mechanisms and enforceability, and institutional capacity to implement and monitor the models. International experiences reinforce these findings. Austria's model illustrates the value of state co-financing in agriculture. France and Germany demonstrate how parametric tools can address flood and cyber risks through advanced modelling. Belgium and Ireland

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demonstrate the integration of real-time data for automated compensation in the service sector. Switzerland highlights that innovation is possible despite regulatory gaps, provided there is sufficient technical expertise and willingness among insurers. United Nations Development Programme-supported pilots, including earthquake-triggered payouts in Mexico and products for informal employment and tourism, confirm that these solutions can be adapted to a wide range of socio-economic contexts.

As observed in cases such as India and Rwanda, the erosion of public trust due to misaligned triggers or opaque criteria can undermine entire pilot schemes; thus, ensuring legitimacy and accountability from the outset is crucial for successful implementation.

For Slovenia and Croatia, the path forward involves a phased and cautious approach. Rather than aiming for system-wide replacement of conventional insurance, parametric products could serve as complementary instruments, particularly in sectors with quantifiable and time-sensitive risks such as agriculture, infrastructure, or municipal services. Suitable starting points might include limited pilot programmes that allow for experimentation with index calibration, legal adaptation, and stakeholder engagement. These pilots would also serve to build trust and awareness among policyholders and regulators.

Legal reforms will likely be required to accommodate parametric contracts within national insurance and civil law systems. Neither Slovenia nor Croatia currently recognises such instruments in a dedicated legislative framework. Parallel investment in data infrastructure and disclosure rules will also be essential to ensure transparency and accuracy in trigger validation. Moreover, any application of enabling technologies, such as smart contracts or artificial intelligence-based indices, must comply with evolving European Union standards, including the Artificial Intelligence Act and the Data Act, and account for risks related to data security, liability, and contract enforcement.

In conclusion, while parametric insurance is not a universal solution, it holds promise as part of a diversified disaster risk financing toolkit. Its utility lies in targeted deployment, especially where it can fill gaps left by indemnity insurance or accelerate relief efforts. It should not be viewed as a substitute but as a complementary tool that strengthens systemic resilience. Transparent communication with end-users, fair treatment of undercompensated beneficiaries, and access to legal remedies will be essential for building and sustaining trust in parametric systems. Ultimately, both Slovenia and Croatia may benefit from participating in EU-level regulatory sandboxes or cross-border pilot projects to safely test and adapt parametric solutions to their respective legal, social, and environmental contexts. A carefully calibrated introduction could enable both countries to integrate parametric insurance in a legally sound, socially responsible, and technically feasible manner, enhancing resilience without overstating expectations.

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Abbreviations

The following abbreviations are used in this manuscript:

NatCat	Natural Catastrophes
EUR	Euro
ECB	European Central Bank
HRK	Croatian kuna
EIOPA	European Insurance and Occupational Pensions Authority

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