

# General Insurer's Financial Resilience Towards Catastrophe Risk: A Conceptual Framework

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## Abstract

The changing climate has led to a significant increase in natural catastrophes worldwide, posing unique challenges to the insurance industry. These catastrophic events, characterized by their infrequency and severe impact, demand specialized risk management approaches and place substantial pressure on insurer capitalization. The insurance industry is particularly vulnerable to the effects of climate change, with catastrophes representing significant financial hazards, including immediate reductions in earnings and statutory surplus, potential forced asset liquidation, the risk of a rating downgrade, and the risk of insolvency. The failure of an insurance company can have far-reaching consequences for the economy, society, and the nation as a whole. In this era of abrupt climate change and heightened catastrophe risk, the resilience of insurers has become a critical concern. Understanding the extent to which these insurance companies can withstand increasing catastrophe risks is essential. However, measuring insurers' resilience is complex and involves multiple factors across different dimensions including financial resilience, for which no clear measurement formula currently exists. This study seeks to contribute to the literature by establishing the conceptual groundwork for understanding and measuring the financial resilience potential of general insurance companies, which may be valuable for researchers interested in empirical investigations of this topic. Additionally, it extends the literature on the role of accounting in climate change risk management by demonstrating how insurance-specific accounting information can be used to assess insurers' financial resilience. Finally, this study is expected to inform public policy discussions on climate change, particularly within the financial sector.

**Keywords:** *climate change; catastrophe risk; insurance resilience; financial stability; risk management*

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## INTRODUCTION

Climate change is a global and long-term problem that involves complex interactions between environment, economy, policy, institutions, society, and technology (Ibrahim et al., 2016). Scientists have associated climate change with greater climate variability (i.e., more frequent and/or severe weather extremes) and a larger potential for abrupt climate change (Linnenluecke & Griffiths, 2012). Consequently, economic losses caused by natural catastrophes could increase significantly, which may compromise the economic growth and sustainable development of a country. From 1993 – 2022, more than 9,400 extreme weather events were reported worldwide causing over 765,000 people to die and direct losses of nearly USD4.2 trillion (Adil et al., 2025). To strengthen the resilience of a nation, particularly the climate-sensitive sectors against climate change and natural disasters, effective climate change adaptation strategy is critical (Alam et al., 2010). Accordingly, several market-based mechanisms have been introduced to address climate change issues including clean development mechanism, fiscal and financial incentives, regulatory requirements (by-laws), and insurance provisions (Begum et al., 2011).

One of the most efficient market-based climate change adaptation instruments to fund catastrophe losses is the insurance policy provided by the general insurers (Clark et al., 2015), which is the focus of this study. In the case of catastrophic events, policyholders rely on insurance companies to pay for their economic losses. Accordingly, the general insurers have to ensure that they are in the position to fully cover the insured catastrophic losses when the need arises. A key challenge for general insurers in dealing with catastrophe risk is that rapid increase in catastrophe exposure concentrations, poor data quality, and relatively short insured loss history bring a high level of uncertainty to risk management (Born & Viscusi, 2006). The severity and magnitude of catastrophic events may give rise to unexpectedly large losses, which will result in a large deficit of funds available for the insured losses. Consequently, the financial performance of the property-casualty insurers (and solvency at the limit) may be adversely affected. In this regard, catastrophe risk may pose a prodigious threat to the general insurers' solvency thereby suggesting a critical need to manage the catastrophe risk well. Accordingly, it is important to understand how resilient are they in facing an increased catastrophe risk.

However, organizational resilience is a complex construct that encompasses multiple factors across various dimensions, including strategic, operational, and financial (Linnenluecke & Griffiths, 2010). Välikangas and Romme (2012) define strategic resilience as an organization's ability to swiftly transform risks into opportunities, identify unique prospects, and act decisively in a competitive environment. In contrast, operational resilience focuses on managing crises and returning to a prior state, often linked to the capacity to reinterpret situations and adjust actions accordingly. A systematic review by Linnenluecke (2017) highlights the fragmented nature of resilience research due to its context-dependent nature across different studies. Accordingly, resilience has been conceptualized in various ways, with limited empirical insights into how it can be detected in the face of future adversities (or the lack thereof) (Linnenluecke, 2017).

As alluded to earlier, insurance plays a crucial role in mitigating the economic and social impacts of natural catastrophes (Terdpapong & Rickards, 2021). However,

there remains a gap in measuring the resilience of insurers to catastrophic weather events. This study seeks to address this gap by proposing a conceptual framework for assessing the *financial* resilience of general insurers to future extreme weather events. Adapted from the resilience framework by Linnenluecke and Griffiths (2012), this paper provides a firm-specific index that assesses an insurer's ability to withstand and recover from extreme climate-related disruptions by integrating two critical dimensions: impact resistance and rapidity.

*Impact resistance* is evaluated through the insurer's coping range, which represents the range of catastrophic losses that an insurer can tolerate without depleting its statutory surplus. The index categorizes insurers into four ranks based on their level of policyholder surplus and claims loss reserves, offering a clear measure of financial strength and risk exposure. This approach accounts for firms that either over- or under-reserve for unpaid claims losses, revealing the degree to which they are prepared for unexpected catastrophic events. *Rapidity*, adapted from the Altman Z-score model and refined by Levy et al. (2020), measures how quickly an insurer can recover after a catastrophe. This is determined by the firm's ability to improve margins, grow revenue, and retain optionality. By combining these two dimensions, this paper offers a comprehensive view of an insurer's financial resilience, making it a useful tool for stakeholders to assess and enhance risk management practices in an era of increasing climate volatility. Particularly, it offers regulators a diagnostic tool for evaluating the vulnerability of insurers to catastrophic risks, thus contributing to the stability of the financial system. Furthermore, this paper contributes to the literature on the role of accounting, particularly the risk assessment function—encompassing vulnerability assessment and adaptive capacity—in climate change risk management (Linnenluecke, Birt & Griffiths, 2015).

The remainder of the paper is structured as follows. The next section provides background information on insurer classifications and economic activities, followed by a review of the relevant literature on organizational resilience in general and insurers' resilience to catastrophic events in particular. The subsequent section presents the proposed framework for assessing the financial resilience of general insurers to future extreme weather events. The paper concludes with a discussion of its limitations and suggestions for future research.

## CONTEXTUAL BACKGROUND AND LITERATURE REVIEW

### Insurance and Its Classifications

Insurance is a form of risk management in which the insured transfers the cost of potential loss to another entity in exchange for monetary compensation known as the premium. Insurers can be classified in several different ways but the basic distinction may be made between private and government insurers. Government insurance is basically rendered by the governmentally organized and managed insurance organizations as the last resort reinsurer for private insurers. Private insurance can be classified according to their legal form of ownership, the type of insurance they sell, their licensing status or the marketing system they employ. Table 1 below presents these classifications of insurance.

**Table 1: Different classifications of insurance (Source: Md Daud, 2018)**

<b>Insurance Classification</b>	<b>General (property-casualty)</b>	<b>Life</b>
<b>Product/line/class</b>	Property (including fire and marine) Liability (or casualty) Health	Life contracts Annuities
<b>Form of ownership</b>		Capital stock Mutual Reciprocals Lloyd's association Health expense association
<b>Marketing (distribution) system</b>	Agency System Direct writers	General agents Branch office system Personal-producing general agent
<b>Licensing status (or place of incorporation)</b>		Domestic Foreign Licensed (or admitted)

Note: The classifications presented above are general, and they may vary across countries depending on regulatory frameworks and market practices.

Broadly speaking, insurance companies can be grouped into six categories of different form of ownership: (1) capital stock insurance companies (also known as proprietary insurers), (2) mutual insurance companies, (3) reciprocals or inter-insurance exchanges, (4) Lloyd's associations, and (5) health expense associations. However, the most prominent types of insurance based on ownership found in the U.S. are capital stock (also known as proprietary) and mutual insurance companies. Generally speaking, a proprietary insurer is a profit-making venture like any other type of businesses and owned by its shareholders. In contrast, a mutual insurer is owned by its policyholders.

This paper focuses on insurance classification based on the product/line/class insurers sell since this type of classification is expected to primarily influence their exposure to extreme weather events.<sup>1</sup> *Life* insurance companies sell life contracts and annuities, and in addition, write health insurance. Specifically, life and health insurance coverage pays death benefits to designated beneficiaries when the insured dies, which include funeral expenses, uninsured medical bills, estate taxes, periodic income payments to the deceased's beneficiary and other expenses. Life and health insurers also sell group and individual retirement plans that pay retirement benefits, health insurance plans that cover medical expenses because of sickness or injury, and disability income plans that pay income benefits during a period of disability. On the contrary, *general* insurance companies, which are the focus of this paper, market all forms of property

<sup>1</sup> Insurers may also be classified (based on the types of products they offer) into three types of insurance firms: (1) **composite insurers** (also known as multi-line insurers) are allowed to sell both life and general insurance coverage; (2) **life or general insurers** are only allowed to write either life or general insurance; (3) **specialist insurers** only offer a class of insurance, normally health insurance.

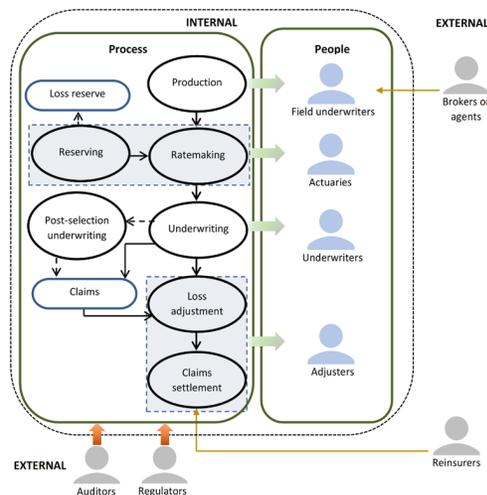
and liability insurance (including health insurance) but do not write life insurance. In particular, property insurance indemnifies property owners against the loss or damage of real or personal property caused by various perils including fire, flood or tornado, while liability insurance covers the insured's legal liability arising out of property damage or bodily injury to others including legal defense costs. In practice, general insurance is also known as property-liability insurance or property-casualty insurance. Casualty insurance is a broad field of insurance that covers whatever is not covered by fire, marine, and life insurance (including auto, liability, burglary and theft, workers compensation, and health insurance). This paper focuses on general insurers, who face the most direct and substantial impacts of climate change (Gupta & Venkataraman, 2024; Moody's, 2018).

## Insurance Firms' Economic Activities

Insurance companies have several significant and unique economic activities. Figure 1 below depicts the participants of general insurance business activities together with their individual roles and interconnections.

Production in insurance industry's context refers to sales and marketing of insurance products. The personnel involved are the agents who sell coverage, who are also called producers. Unlike production, claims settlement will normally take place towards the end of the insurance cycle. The objectives of insurers in settling claims include verification that the loss occurred and was covered under the terms of the insurance contracts, fair and prompt payment, and personal assistance to insured parties.

As can be seen in Figure 1, insurance companies have several important functions that are not found in other types of businesses. The whole process is arbitrarily a cycle where past claims are used to form opinion and estimation about future claims. This process is what is called 'reserving' where insurers have to provide a forecast of loss reserve adequate to meet future losses. This is in turn used in ratemaking to set the rate and hence premium. As can be seen above, actuaries are involved in both reserving and ratemaking process.



**Figure 1: Key economic activities and actors in insurance transactions**  
(Source: Md Daud, 2018)

In essence, actuaries provide expertise in three areas that are reserving, ratemaking (pricing) and capital modelling. In reserving, actuaries apply statistical techniques to assess the likely outcome of general insurance liabilities, typically and the provisions that are needed for reporting purpose. As reserving is highly subjective and uncertain, the final loss reserve figures reported in the financial statement are influenced by not only the actuarial methods (chain ladder, Bornhuetter–Ferguson, stochastic methods etc.) and assumptions (loss development factors, tail factors, expected loss ratios), but also management overlays and conservatism, and response to regulatory regimes (i.e., risk-based capital).

Ratemaking, on the other hand, involves pricing activities where actuaries assess the frequency and average amount of claims to estimate premiums. For insurance companies, the process of pricing insurance products is more difficult because the product cost is not known until total losses and expenses are known, which may take several months or even years. This is mainly where actuaries play significant roles in insurance industry by determining the rates and premium. The main objective of rate-making is to calculate premiums that will make the business profitable, enable the company to compete effectively with other insurers, and allow the company to pay claims and expenses as they occur. Lastly, in capital modelling, actuaries project both the liabilities and assets of insurer to assess solvency and future capital needs.

Another function of insurance is underwriting. Underwriting is a process of selecting, classifying and pricing applicants for insurance, which is handled by underwriters. Simply put, underwriters decide whether to accept or reject an application and classify approved applicants to a certain rating group to ensure riskier applicants pay higher premiums as compared to applicants deemed less risky. They normally strive to select certain types of applicants and to reject others so as to obtain a profitable portfolio of business.

Reinsurance is shifting part or all of the insurance originally written by one insurer to another insurer. There are a few reasons why insurers use reinsurance, the most common ones are (1) to improve underwriting capacity (2) to stabilize profits (3) to reduce the unearned premium reserve (4) to provide protection against catastrophic loss (5) to enable an insurance company to retire from a line of business or from a territory, and (6) allow an insurer to obtain the underwriting advice and assistance of the reinsurer.

An important function of an insurance firm but is not directly embedded in an insurance contract is investment. Insurance companies have two main sources of income, premiums and investment income. The main source comes from their core business of selling insurance products. This is the underwriting side of the ledger. However, premium income may or may not be sufficient to pay losses and cover expenses. As premiums are paid in advance, insurance companies can invest these funds and generate income. Investment income helps to hold premium lower and offset any losses the insurer may sustain on the underwriting side. As a result, investment becomes an important function in insurance industry. Good investment strategies through an effective investment function make a lot difference to insurance companies' performance.

The whole process will lead to the creation of financial reports which are governed by accounting standards and regulatory-related guidance. These reports are subject to audit by independent external auditors and to scrutiny by the regulators.

### **Climate Change Impacts on Insurance Industry**

Empirical evidence indicates that climate change has contributed to rising losses from natural disasters due to increases in the frequency and intensity of extreme weather events such as floods (IPCC, 2018; Linnenluecke & Griffiths, 2012; Zhou et al., 2024). Beyond property damage, climate variability such as heavy rainfall or drought poses significant risks to agricultural production and farmers' incomes (Jørgensen, Termansen & Pascual, 2020). As emphasized by Gupta and Venkataraman (2024), climate risks, both acute (e.g., storms, floods) and chronic (e.g., gradual temperature and sea-level rise), exert direct and indirect impacts on the insurance industry that must be thoroughly assessed and managed.

Catastrophe insurance plays an important pre-disaster risk management role by reducing the financial burden on policyholders and supporting faster post-disaster recovery (Zhao et al., 2020; Zhou et al., 2024). Historically, socioeconomic developments such as rising asset values and exposure have been the dominant drivers of increasing catastrophe losses. However, future losses are expected to escalate further due to the combined effects of societal change and climate change (Bouwer et al., 2007). Insurers also face challenges arising from shifts in the locations, frequencies, and intensities of catastrophic and non-catastrophic weather events, including storms and local precipitation (Mills, Lecomte & Pears, 2002). Consequently, insurers are likely to face higher average loss burdens and greater year-to-year volatility. Acute climate events have already caused estimated global insurance losses of around USD 100 billion annually over the past five years (Moody's, 2023), directly affecting the profitability of both insurers and reinsurers.

In summary, climate change threatens the sustainability of insurers in two key ways. First, the increase in aggregate losses may necessitate substantial premium adjustments and additional solvency capital (Zhou et al., 2024). Second, foundational principles of insurance (i.e., risk pooling, diversification, and risk transfer) may be strained as climate-exposed risks become more correlated, raising concerns about long-term insurability (Charpentier, 2008; Thistlethwaite & Wood, 2018; Courbage & Golnaraghi, 2022). If climate risks continue to evolve rapidly, these pressures may challenge the fundamental viability of traditional insurance models.

A further concern lies in pricing adequacy. Premium income may lag behind actual claims development if climate-induced risk changes are not fully reflected in insurers' pricing models. When insurers rely heavily on historical loss data, they risk underestimating exposures associated with low-probability but high-severity catastrophic events (Tucker, 1997). This mismatch can lead to inadequate premiums, erosion of technical reserves, and ultimately pressure on profitability and solvency. The challenge is intensified when catastrophic losses escalate faster than insurers can revise their pricing assumptions or when regulatory constraints limit premium adjustments.

Even so, the sector's resilience is not static. It may be strengthened by factors such as greater diversification and firm size, integration with broader financial services, the availability of advanced financial instruments for risk transfer, and more flexible contract structures (Botzen, Van den Bergh & Bouwer, 2010). It may be reinforced through greater diversification and firm size, integration with broader financial services, the use of advanced financial instruments for risk transfer, and flexible contract structures (Botzen, Van den Bergh & Bouwer, 2010). While insurers can typically adapt to gradual shifts in risk, rapidly evolving or unprecedented climate risks pose more complex adaptation challenges that further test the robustness of traditional insurance mechanisms.

Despite these mounting challenges, earlier evidence suggests that many insurers historically did not view climate change as a serious concern (Dlugolecki, 2000; de Rooij & Van den Bergh, 2005 in Botzen et al., 2010). While adaptation strategies can help contain rising risks, they are unlikely to fully offset the upward trend in losses driven by societal developments and climate change. Insurers can address growing climate risks through four traditional strategies: limiting exposure, adjusting premiums, implementing risk mitigation measures, and transferring risk (Dlugolecki, 2000).

Beyond traditional strategies, coordinated efforts between insurers and governments can support long-term climate mitigation and adaptation. Nagaichuk et al. (2020) argue that insurers should enhance climate-related risk assessment and demonstrate readiness for climate change impacts to regulators, analysts, and customers. Mitigation and adaptation policies—such as supporting emissions reduction, investing in risk assessment research, raising public awareness, and promoting adaptation strategies—can help preserve the insurability of climate-related risks (Botzen et al., 2010). These efforts may also be cost-effective given insurers' high exposure to climate-related losses. Indeed, the role of insurers has increasingly expanded from traditional risk transfer toward facilitating prevention and resilience-building (Nagaichuk et al., 2020). For example, in response to rising flood risks, insurers have invested in the development of improved flood insurance schemes (Hudson, Botzen & Aerts, 2019).

A key theme emerging from the above discussion is that climate-related losses in the insurance industry are substantial, increasing, and characterized by deep uncertainties. Unlike traditional risks, climate risks exhibit limited historical precedent, nonlinear dynamics, and cross-scale variability (Linnenluecke, Griffiths & Winn, 2012). As a result, climate change is widely regarded as one of the most significant financial risks facing the insurance industry (Zhou et al., 2024). In attempts to quantify climate impacts on insurance balance sheets, actuarial indices such as the Actuaries Climate Index™ (ACI) have been developed. However, catastrophic losses in practice may far exceed model-based expectations due to forecasting difficulties and heightened correlations among climate-exposed risks (Moody's, 2018).

Consequently, catastrophe risk management has become increasingly important. BaFin (2020) highlights that sustainability risks are now material for insurers and may affect all business units and risk categories. A study by Gatzert, Reichel, and Zitzmann (2020) similarly found climate change to be among the most significant sustainability issues facing the industry. Despite this, empirical evidence on catastrophe risk

management practices—particularly among general insurers—remains limited. One of the few studies in this area, Thistlethwaite and Wood (2018), reports that U.S. insurers have yet to fully integrate climate change considerations into their risk management frameworks. They find that firms with nested organizational logics often assume their existing practices adequately capture climate risk, even though climate uncertainty demands more adaptive and scaled approaches. Reinsurers, however, appear to be more proactive, rescaling their risk management practices in response to increasing catastrophe risks (Institute and Faculty of Actuaries, 2015; Kunreuther et al., 2013; Thistlethwaite & Wood, 2018).

### **Insurers' Resilience to Catastrophic Events**

In light of the growing impacts of climate change and catastrophe risks on the insurance industry, assessing insurers' climate risk exposure has become increasingly critical (Gupta & Venkataraman, 2024; Zhou, 2024). Equally (if not more) important, however, is evaluating the extent to which insurers can withstand and subsequently recover from catastrophic shocks, as this resilience directly affects their ability to meet claims obligations and remain viable in the market, carrying significant policy implications (Gupta & Venkataraman, 2024). Reflecting this need, several studies have proposed resilience indicators for the insurance sector. For instance, Holzheu et al. (2019) developed macro-level insurance resilience indicators that compare existing protection gaps with the level of coverage required globally. Their indexes assess how effectively insurance shields households from natural catastrophes, death, and catastrophic health-care costs. Further, exploiting the Covid-19 crisis, Cornaro (2023) proposed a financial resilience measure for a group (network) of insurance firms. The financial resilience index analyses an insurance network's ability to absorb shocks. It accomplishes this by modelling how a shock to one insurer propagates through the network and impacts other insurers. The indicator focusses on the clustering coefficient, which measures how interrelated the insurers are. If a shock significantly alters this interconnectivity, the network is deemed less resilient. The resilience score combines these factors to determine which insurers are most important in ensuring the general stability of the insurance industry.

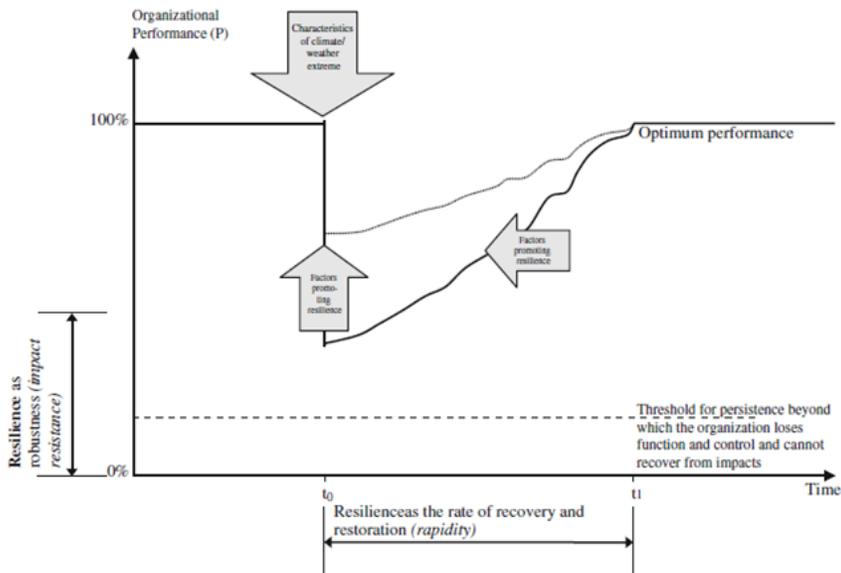
In addition to the abovementioned resilience studies, a number of past research examine financial metrics aftermath catastrophic events. Focusing on general insurers in Thailand, Terdpaopong and Rickards (2021), examined key performance indicators before, during, and after the 2011-flood. In so doing, they employed loss ratio (LR), operating expense ratio (OER), combined ratio (CBR), return on assets (ROA), return on equity (ROE), and the debt-to-equity ratio (DE). Data Envelopment Analysis (DEA) was also used to evaluate these insurers' technical efficiency in terms of operating profit compared to assets. Key measures such as ROA, ROE, and profit margins saw significant declines during and after the flood year. The average technical efficiency of these businesses also fell, particularly for those with fewer resources (smaller businesses). Larger organizations with more assets were shown to be more robust, retaining better efficiency scores even after the floods.

The above review reveals the absence of a measure to gauge an insurer-specific financial resilience potential towards catastrophe risk in the insurance literature. This is the gap this paper seeks to address.

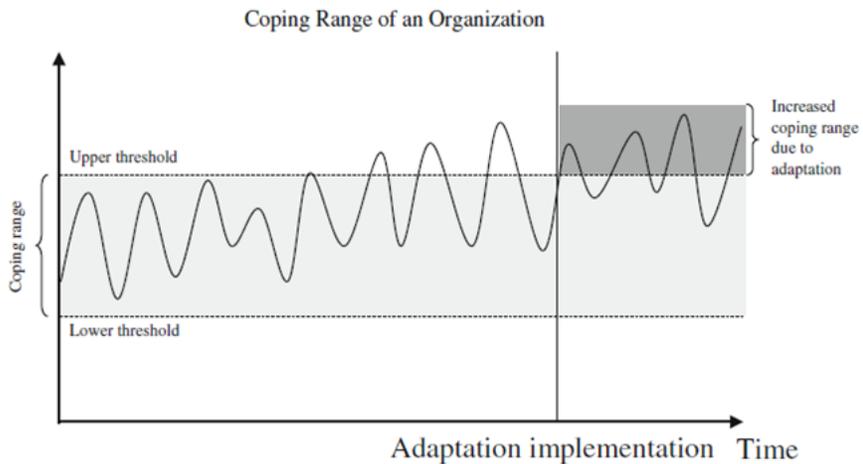
## GENERAL INSURERS' RESILIENCE FRAMEWORK

### Adapting Organizational Resilience and Coping Range Frameworks for General Insurers

Linnenluecke and Griffiths (2012) developed a framework to gauge organizational resilience potential, which is determined by a firm's impact resistance and rapidity, as depicted in Figure 2. Impact resistance, is in turn, influenced by the firm's coping range .



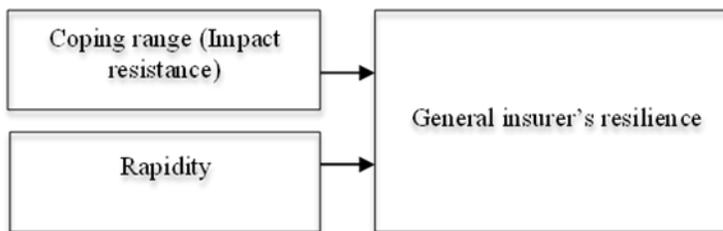
**Figure 2: Organizational resilience framework**  
[Source: Linnenluecke and Griffiths (2012)]



**Figure 3: Organizational coping range framework**  
[Source: Linnenluecke and Griffiths (2012)]

The organizational resilience and coping range frameworks presented in Figures 1 and 2 are adapted to an insurance context as follows. Organizational exposure to an adverse event occurring at  $t_0$  can cause sufficient damage to the general insurer such that its earnings (or highly likely statutory surplus) is reduced by a certain percentage. The extent to which statutory surplus is maintained (i.e., the extent to which statutory surplus is not driven to zero) reflects the impact resistance to a given shock (McDaniels et al., 2008). The impact resistance of an insurer increases with the width of its coping range. Replenishment of the statutory surplus is expected to occur over time, as indicated in Figure 3, until the time  $t_1$ , when it is completely replenished. The rate with which recovery and replenishment are achieved reflects the rapidity (Adger, 2000).

In the insurance context, a coping range represents a range of catastrophic losses that an insurer can tolerate without experiencing statutory surplus depletion. The core of the coping range shows ideal conditions for insurers' activities where the insured payable losses are within the estimated figures. The edges of a coping range indicate boundaries beyond which insurers experience significant financial consequences such as the depletion of statutory surplus (Linnenluecke & Griffiths, 2012). Climate change increases the risk that conditions outside the boundaries of the coping range occur. Such conditions can occur if the insured losses of an individual or a combination of catastrophic events significantly deviate from 'expected' losses (Linnenluecke & Griffiths, 2012). Together, the organizational resilience and coping range models discussed above suggest that the general insurers' resilience to natural catastrophic events is a function of their coping range (and impact resistance), and rapidity. This conceptual framework is presented in Figure 4 below.



**Figure 4: General insurer's resilience towards catastrophic weather events**

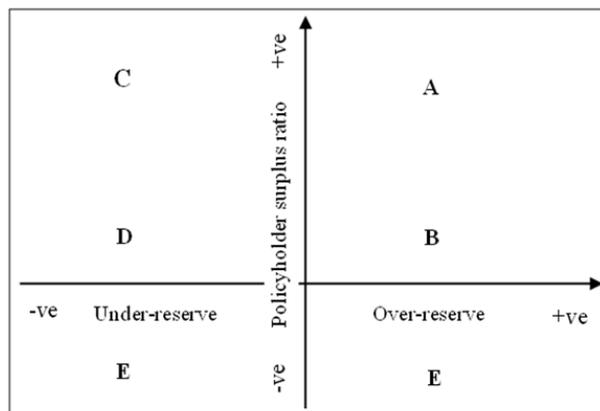
### **Measuring Coping Range and Rapidity for General Insurers**

The next question that arises is: how should the coping range and rapidity be operationalized in the context of insurance? Arguably, the coping range of a general insurer is largely determined by the level of its policyholder surplus relative to its estimated outstanding claims losses. Policyholders' surplus (also known as statutory surplus) represents the difference between an insurer's assets and liabilities. It serves as a cushion that can be drawn upon when liabilities exceed expectations; the greater the surplus, the stronger the financial security for policyholders. From an accounting perspective, the surplus reflects the insurer's equity over time. Hence, an insurer with a higher ratio of policyholder surplus to outstanding claims losses faces lower risk and demonstrates greater resilience to catastrophic events, where claims may rise unexpectedly.

This risk exposure, however, may be influenced by the insurer's reserving practices. Claims reserves typically constitute about two-thirds of total liabilities. Therefore, even minor under-reserving errors can substantially increase the risk of insolvency (Beaver & McNichols, 1998; Weiss, 1985). Consistently, large reserve errors and inadequate reserves have been identified as major contributors to bankruptcies in the U.S. general insurance sector (Leadbetter & Dibra, 2008; Kelly, 2015). This evidence highlights that under-reserving poses significant risks for general insurers, whereas over-reserving tends to have the opposite effect and can serve as an effective risk management tool.

In light of the above, this study proposes that the coping range be measured by the ratio of policyholder surplus to estimated outstanding claims losses, moderated by the insurer's reserving practices; specifically, whether it under- or over-reserves (with under-reserving representing higher risk). The following ranking of coping range is proposed, as illustrated in Figure 5:

- A. **Highest ranked:** A company with a high policyholder surplus to outstanding claims losses ratio and that over-reserves its unpaid claims losses.
- B. **Upper intermediate:** A company with a low policyholder surplus to outstanding claims losses ratio but that over-reserves its unpaid claims losses.
- C. **Lower intermediate:** A company with a high policyholder surplus to outstanding claims losses ratio but that under-reserves its unpaid claims losses (this company is exposed to a higher financial risk relative to the B-ranked).
- D. **Lowest ranked:** A company with a low policyholder surplus to outstanding claims losses ratio and that under-reserves its unpaid claims losses.
- E. **Red zone:** A company with a negative policyholder surplus to outstanding claims losses ratio (a condition unlikely to occur due to strict regulatory requirements such as risk-based capital standards).

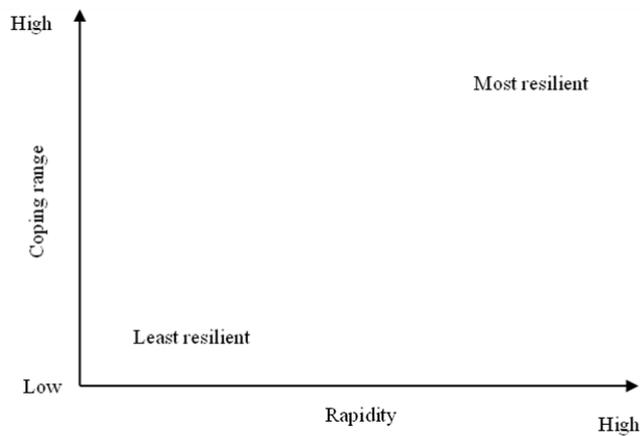


**Figure 5. Insurer coping range ranking**

Drawing on Levy et al. (2020), this study suggests that rapidity is measured using the three-component Altman's Z-score (i.e., the higher the Z-score, the quicker an insurer will bounce back aftermath a catastrophic event). The three components are margin

improvement, revenue growth, and optionality (retained additional optional-investment opportunities). Working capital and market equity value were part of Altman's original score; but Levy et al. (2020) included the former determinant as part of optionality and recognized that the latter, market value, is externally driven and ultimately a product of the other factors. A company's Z-Score goes up if it has a well-established ability to grow margins (measured as EBIT/assets) while increasing revenues (measured by revenue/assets) and maintaining optionality (measured by retained earnings/assets).

After both coping range and rapidity are assessed, they can be plotted on a two-dimensional graph, with rapidity on the X-axis and coping range on the Y-axis, to evaluate a general insurer's financial resilience, as illustrated in Figure 6. This mapping provides stakeholders with insights into the insurer's overall potential to withstand and recover from catastrophic events.



**Figure 6: Insurer financial resilience**

### Scoring and Aggregation of Resilience Dimensions

To operationalize the proposed resilience framework, numeric scores are assigned to both coping range and rapidity, allowing for a consistent, quantifiable assessment of insurers' financial resilience. *Coping range* is ranked categorically from A to E based on the ratio of policyholder surplus to estimated outstanding claims, moderated by reserving practices. To translate these ranks into numerical scores, a simple scale can be applied, for example: A = 5, B = 4, C = 3, D = 2, and E = 1. Firms within each rank can be further differentiated using normalized surplus-to-claims ratios to capture finer variations in financial strength.

*Rapidity* is measured using a continuous Z-score adapted from Levy et al. (2020), incorporating margin improvement, revenue growth, and optionality. For comparability with coping range scores, the Z-score may be standardized (e.g., using z-standardization or min-max scaling) or discretized into ordinal categories if needed. The continuous approach is preferable for preserving information about recovery potential.

The two dimensions can then be combined into a *single composite resilience score*. A straightforward method is a weighted sum or average, where coping range and rapidity are either equally weighted or assigned weights based on their relative importance for regulatory and risk management purposes. This approach allows insurers to be positioned on a two-dimensional resilience map (coping range on Y-axis, rapidity on X-axis), as illustrated in Figure 6, providing a clear, visual representation of both their shock-absorption capacity and recovery potential.

The above operationalization ensures transparency and consistency while maintaining flexibility for future refinement, such as adjusting weights or incorporating additional risk factors. By defining a clear scoring and aggregation methodology, the framework becomes both practical for empirical validation and interpretable for stakeholders, including regulators, investors, and risk managers.

### **Implementation Challenges**

While the proposed framework provides a structured approach to assessing the financial resilience of general insurers, several practical challenges may arise in its real-world implementation. First and foremost, while the framework appropriately relies on historical data to quantify each insurer's coping range and rapidity, it is important to acknowledge that the resulting resilience score provides a *relative* rather than an absolute measure of financial resilience. That is, the framework ranks insurers based on their comparative ability to withstand and recover from catastrophic shocks given their current financial position, reserving practices, and historical performance patterns. However, the adequacy of an insurer's resilience is inherently conditional on the magnitude and nature of future catastrophic events, which may exceed historically observed loss distributions. In such cases, even insurers classified as highly resilient could encounter strain if the event severity surpasses the assumed stress scenarios embedded in historical data. This fact does not invalidate the framework but highlights the need for careful interpretation: the resilience index reflects an insurer's *relative preparedness under plausible but not boundless catastrophe conditions*.

Other implementation challenges include data availability and quality, dynamic nature of rapidity, and stakeholder interpretation. Accurate measurement of coping range and rapidity requires detailed data on policyholder surplus, outstanding claims reserves, and financial performance. Not all insurers report these data with sufficient granularity, particularly private unlisted insurers, and differences in accounting or actuarial methods may hinder cross-firm comparisons. Additionally, rapidity can fluctuate due to short-term operational decisions, market conditions, or regulatory changes. Capturing a stable, forward-looking measure that accurately reflects an insurer's true recovery potential requires careful consideration of these temporal dynamics. Finally, even with standardized scoring, translating the combined resilience score into actionable insights may pose difficulties for regulators, investors, or management teams. Clear interpretive guidelines will be necessary to ensure that the framework informs supervisory decisions, capital planning, and risk management strategies effectively.

## CONCLUSION

To the best of the author's knowledge, this study is the first to propose a definitive and quantifiable measure of financial resilience specifically designed for insurance companies. Building upon prior generic frameworks of organizational resilience, particularly the dimensions of coping range and rapidity, this study contextualizes these constructs within the financial and operational characteristics of general insurers. The framework advances understanding by demonstrating how resilience, often viewed abstractly, can be systematically translated into measurable indicators that reflect insurers' financial capacity to absorb, adapt to, and recover from catastrophic shocks.

Despite the need for a careful interpretation of resilience as a relative and conditional measure, the conceptual model contributes to the literature in several important ways. First, it moves beyond the predominantly qualitative discussions of resilience in the insurance and risk management literature by offering a structured and measurable approach. Second, it integrates financial accounting measures such as policyholder surplus, claims reserves, and the modified Altman's Z-score into a resilience framework, thereby bridging organizational theory with practical financial performance metrics. Third, the model acknowledges the dynamic interplay between financial soundness, reserving behavior, and adaptive capacity, emphasizing that an insurer's resilience depends not only on its capital adequacy but also on its prudent risk management and capacity to respond swiftly to disruptions.

From a practical standpoint, the proposed framework holds several implications. For regulators and policymakers, it offers a potential diagnostic tool for assessing the vulnerability of insurers to climate-induced and other catastrophic risks, complementing existing solvency and capital adequacy assessments. For insurers, it provides a self-assessment mechanism to benchmark resilience capacity relative to peers, informing strategic decisions on capital management, reinsurance, and risk diversification. For investors and rating agencies, the framework can enhance risk-based evaluations by incorporating resilience as a distinct dimension of financial stability and long-term viability.

Despite its potential contributions, the study is not without limitations. The proposed measure has yet to be subjected to empirical testing, and therefore, its reliability and predictive validity remain to be established. Future research is therefore encouraged to test the framework using real-world data and multiple complementary empirical approaches. A useful starting point is an event study that examines how insurers with differing levels of coping range and rapidity perform following actual catastrophic weather events. If insurers classified as more resilient experience smaller solvency deterioration or faster recovery, this would provide strong initial evidence of predictive capability. Researchers may employ panel regression models using lagged coping range and rapidity scores to assess whether these dimensions predict subsequent changes in financial outcomes such as solvency ratios, underwriting results, or profitability aftermath extreme events. Building on this, a Difference-in-Differences (DID) design could compare insurers in catastrophe-affected regions with those in unaffected regions before and after an event. Demonstrating that insurers with higher prior resilience scores experience significantly smaller negative changes after the shock, relative to the control group, would offer stronger causal evidence of

predictive validity. To further enhance comparability, future studies may also utilize matched-pair or propensity-score matching techniques to compare insurers with similar characteristics such as size, underwriting mix, or reinsurance intensity, but differing levels of resilience according to the proposed index. Consistent outperformance of high-resilience insurers relative to matched peers would reinforce the discriminatory and predictive strength of the framework. Additionally, survival (time-to-recovery) analysis offers a rigorous method to validate the rapidity dimension by modelling the duration required for insurers to return to pre-event performance thresholds. Insurers with higher rapidity scores should demonstrate significantly shorter recovery periods.

Future research could also refine the weighting of resilience components. Additionally, the framework could be extended to incorporate qualitative factors such as governance effectiveness, risk culture, and strategic flexibility, which complement financial metrics but are more difficult to quantify. Researchers may also explore how financial resilience interacts with profitability, cost efficiency, and firm value, providing a more holistic assessment of insurer performance under stress.

In conclusion, this study lays a foundation for a new line of inquiry into the financial resilience of general insurers. By offering a theoretically grounded and practically relevant measurement framework, it aims to stimulate empirical research and inform policy debates on the insurance sector's preparedness for an increasingly volatile and climate-challenged future. Ultimately, enhancing insurers' resilience is not only critical for their own sustainability but also for ensuring the stability of the broader financial system and the protection of policyholders in times of crisis.

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