JMFS
Journal of Management and Financial Sciences

Volume XIX
•
Issue 60
pp. 45–60
SGH Warsaw School of Economics
Collegium of Management and Finance

Roland Eisen, PhD, Dr. h.c.
Professor Emeritus
Goethe University Frankfurt

The Theory of Mutual Insurance: Some Notes on History, Theory, and an Application to Climate Change*

Abstract

We observe dynamic trends of increasing magnitude in natural disasters and climate-related damages, which ultimately lead to probability distribution functions with very fat tails. This implies a "race in the extreme tail between how rapidly probabilities are declining and how rapidly damages are increasing" [Weitzman, 2009, p. 1]. To cope with these significant long-term risks, characterised by a high degree of uncertainty and correlated events, standard economic instruments and insurance products are inadequate. Even the appeal to capital markets and the securitisation via ILS leads to a huge remaining protection gap. Therefore, either a very high level of capital reserves is needed (in the *reserve theory of insurance*) with all its associated problems, or an intergenerational allocation is called for, which can only be provided by the State or *Mutual Insurance*. The goal of this paper is to convince readers that mutual insurance is the only solution for coping with these disaster risks. It therefore starts with a short history of Mutual Insurance, gives a concise introduction to the Mutual Insurance Theory, and ends with an application of this theory to the risks and damages of climate change.

Keywords: environmental damages, cost of damages, new insurance products, securitisation, mutual insurance
JEL Classification: D02, G22, N20, N50, Q54

* Paper presented at The Third Global Conference on the History of Risk and Insurance, 3–4 July 2025, Warsaw School of Economics, Poland. Parts of this paper were presented at the University of Economics in Krakow's Conference *Insurance in European Countries – Economics and Legal Issues,* November 2023, under the title *Uncertain Climate Change, Increasing Risks, and Mutual Insurance*. I would like to thank two anonymous referees for their very constructive comments.

Introduction

We are living in a world of multiple crises. In addition to COVID-19, which has not yet fully disappeared, we face two further challenges: demographic change with its "ageing societies", and climate change. While demographic changes can be (and are) seen by most demographers as a well-known process with only minor risk, climate change is – in the opinion of most scientists – associated with great and increasing risks, and involves a great array of uncertainties. Therefore, the essence of the economic problem posed by climate change lies in the exceptional nature of its far-reaching consequences, which pose a serious challenge when setting interest rates or determining whether and how to discount the distant future [Gollier, 2013; Nordhaus, 2007]. There is also a second uniqueness that relates to the unsure outcomes of a stochastic process, the unknown variables related to the (uncertain) technological developments through which environmental damage can be prevented, reduced, controlled or mitigated. This is further linked to the question of the "appropriate way to represent the damages caused by global warming" in the (Social) Welfare Function (SWF), as Weitzman [2009] put it. Should these environmental damages be treated multiplicatively, and thus substitutable with other goods? This, in turn, implies that climate changes "drive up only the prices of food or increase the demand for air conditioning" [Weitzman, 2009, p. 1], a phenomenon also known as "climateflation". Or perhaps the damages should be treated additively in SWF, where the "impact of climate change is on things that are not readily substitutable with material wealth, such as biodiversity and health" (ibid.)? Ultimately, these factors lead to probability distribution functions with very fat tails!

To cope with these dynamic and uncertain processes, sophisticated economic arrangements and insurance products are called for, which is where *mutual insurance* comes into play. This paper therefore proposes an innovative solution or framework for addressing the challenges posed by the significant threats associated with climate change, as well as environmental risks and damages. The paper starts with a short overview of the history of mutual insurance, followed in the second section with a concise theoretical discussion highlighting the specific characteristics of mutual insurance, while the third section demonstrates that the insurance industry has responded to certain catastrophes by introducing innovations that combine (re) insurance and capital markets; however, the "protection gap" remains, where mutual insurance offers several advantages with respect to the "cascading of big uncertainties" [Weitzman, 2009]: *Mutual insurance* is a solution when risks are high, probabilities are unknown, and events are correlated [Skogh, 1999]. The application of mutual insurance not only provides financing but also incentives to prepare for a disaster. A summary is presented in the conclusion.[1]

[1] Since this is a theoretical paper, the research method used can be described as a critical literature review, using national and international sources as well as documents.

A brief history of the roots of mutual insurance

According to Werner Mahr [1951, § 5, pp. 39 sqq.], the modern insurance organisation has two roots: on the one hand, the "*principle of mutuality*", and on the other, the "*principle of entrepreneurship*", where profits serve as the driving force. However, while Mahr believed that these two roots unite in the modern "rational insurance company", these two principles coexist and can be described as two different "*theories of insurance*": Allan Willet's "*reserve theory*" [1901] and Kenneth Arrow's "*mutuality theory*" [1970]. According to Willett, insurance is defined as "a fund accumulated to cover uncertain losses" [ibid., p. 71]. Consequently, an insurance company exists to organise operations (we call this insurance technology: making decisions regarding the distribution channel and underwriting policy, the composition of the underwriting portfolio, calculating premiums, claims settlement, etc.[2]) and to use the increasing returns inherent to the accumulation of these reserves. The *reserve theory* of insurance uses the applicability of the law of large numbers and of the central limit theorem. Consequently, an increase in the number of insured individuals in a portfolio tends to lead to a concentration of the probability density of the average loss around the mean value [Eisen, 2021, p. 225]. According to Arrow, however, insurance is the exchange of money today for money payable tomorrow, contingent on the occurrence of specific events. Here, insurance companies are *intermediaries* that buy and sell preferred bundles of contingent claims to economic agents.[3]

The *theory of mutuality* of insurance – or rather, the *principle of mutuality* itself – has a long history. Following Mahr [1951, p. 31], we can begin with the "communal" insurance relationship, where the risk borne by other economic agents stems from an ethical obligation (responsibility) to mutual assistance within the family, parenthood, and rural communities. In rural communities, neighbours still help one another to rebuild burned-down homes via services in kind. "Everywhere, communities are the first insurance organisations" [Mahr, 1951, p. 31]. The source of insurance is solidarity, already present in prehistoric times. However, "insurance" is not a goal; the term does not even exist, and protection is granted only to members who respect the ethics of the group, and applies only to risks such as death, illness, old age, fire, flooding, and crop failure.

The next step, according to Mahr [1951, p. 33], is a "covenant relationship" in which ensuring the security of economic activity against dangers and risks is a deliberate, specific task that goes beyond other obligations arising from the common good. Covenant insurance relationships were attempted, where communities with limited resources were unable to deliver the necessary security against the dangers arising from everyday life in society. The guilds "took over the whole body" [R. Ehrenberg, cited by Mahr, ibid.]. In England, the "judicia civitatis

[2] See Zweifel, Eisen, Eckles [2021].

[3] In principle today three different theories of insurance should be differentiated, although the *capital market theory* is almost identical to the theory of mutuality, so it will not be discussed here; but see Marshall [1974], Venezian [1983] and Doherty [1984].

Lundonia" (formed around 925–940 under king Athelstan) were guilds whose members were obliged to mutual assurance in case of theft. One of the oldest English guilds, that of Exeter, rendered not only funeral care but also granted assistance in the event of fire. Such guilds were first recorded in the time of Charlemagne, and the Middle Ages were traversed by such organisations in many forms, such as craft guilds, brotherhoods, cooperatives and trade unions.

In modern times, such covenant relationships can be found in England, for example in the Friendly Societies, which have existed since 1750, and in trade unions, which merged with such Friendly Societies during the period when they were banned (1799–1824).[4]

From the general characteristics of communities that provided assistance only in emergencies, specialised organisations emerged whose sole purpose was to assume risk. They conducted typical insurance operations, collecting funds from their members to cover losses or by distributing the losses among members. From the general guilds, specialised guilds emerged, with specific objectives for specific dangers, in particular fire or death: a remarkable step from universalism to specialisation!

The support of the guilds was regulated in various ways, an interesting example being the Icelandic Grey-Goose-Laws (Grágás)[5] of 1118, which also regulated the consequences of fire: Three rooms had to be rebuilt, clothing and daily food provided, but not jewels; and only half of the losses were reimbursed [Mahr, 1951, p. 41]. Initially, only services in kind were given to rebuild and to furnish. In towns, the services gradually began to be paid in cash, and anyone could insure their homes with more than one guild.

Fire insurance developed in rural areas, due to the narrower and lighter buildings in towns; moreover, fire insurance was initially limited to fire prevention. It was not until the 16th century that the first fire guilds were established, although restricted only to members of the "middle or upper classes".

Significant progress was made in Hamburg: on 3 December 1591, 100 Hamburg households licensed to brew entered into the first fire insurance policy, and by 1676, 46 such policies had been issued, with around 4600 properties (or messuages) insured in Hamburg. However, certain shortcomings emerged. Several major fires (1606, 1626 and in particular a fire on 23 June 1676) revealed the inadequacies of the fire department and demonstrated the limited efficiency of the policies. Consequently, the city counsel of Hamburg appointed a "Delegation to form the General-Feuer-Cassa", which proposed a citywide fire regulation. Thus, on 17 December 1676 the establishment of the "General-Feuer-Cassa" was enacted, consolidating all the previous fire prevention agreements [Mahr, 1951, p. 43]. The establishment of 1676 proved so effective that only in 1753 was a decision made to implement several significant expansions. London (in 1680), Harburg (in 1677), Copenhagen (in 1681) and Magdeburg (in 1685) followed suit.

---

4 An interesting aside are (mutual aid) tontines, which flourished in nineteenth century Ireland and Scotland! See McDiarmid [2025].

5 See https://en.wikipedia.org/wiki/Grey_Goose_Laws (accessed: 02.06.2025). The German version is much more comprehensive: https://de.wikipedia.org/wiki/Grágás.

An attempt made in 1685 by the Great Elector Wilhelm to establish a Feuer-Cassa similar to the Hamburg example in Berlin, Cölln and Friedrichswerder failed because the citizens feared it would only become a new financial burden. However, Frederick William's establishment of the Berliner Societät in 1718, which was founded in consultation with the residents, was a success. According to Georg Helmer [cited in Mahr, 1951, p. 45], the 18th century, while building on the foundations of the 16th and 17th centuries, can be called "the classical century of the establishment of German public fire insurance" (or fire insurance based on public law).[6]

In addition to these government initiatives, private mutual insurance organisations also emerged – occasionally in the 15th century, more frequently in the 16th century – offering coverage for fire, furniture or individuals; however, most of them failed. The reasons varied, perhaps including ecclesiastical or religious resistance, or even the bad experiences of the Hamburg fire insurance contracts. As Werner Mahr [1951, p. 46] notes, it was only after positive experiences with public or government insurance organisations that people could rely on, but also following the emergence of liberalism with its unfavourable attitude toward government initiatives, that the establishment of mutual insurance became fashionable. The ventures of Ernst Wilhelm Arnoldi (1778–1841) were pioneering and even epoch-making: the Gothaer Feuerversicherungsbank a. G. 1821 (a. G. stands for "auf Gegenseitigkeit", or mutual) and in 1828 the Gothaer Lebensversicherungsbank a. G. The ideas of "the creative individual" [Mahr, 1951] combined with disappointment over the compensation paid by an English company for a tobacco factory belonging to a close relative of Arnoldi that burned down in 1818, led to the formation in the Gothaer society of an organisational form of mutual insurance.

According to Mahr [1951, ibid.], this can be summarised as ***Thesis 1***:

Starting with the covenant relationship, this Germanic or North European source of the modern insurance relationship found its perfection in the mutual principle.

A curmudgeon's guide to Mutual Insurance Theory

Assuming equivalence between Arrow's *ideal insurance model* and the *mutuality theory,* certain theoretical arguments must suffice.[7] Here, a price exists for every state of nature, which is the same for every state only if the sums of the losses are the same. Then, the equilibrium set of prices supports a consumption and income distribution among all members, which is – given the Expected Utility Theory – Pareto optimal.

To illustrate the differences, the *mutuality theory of insurance* is contrasted with the *reserve theory of insurance*. According to Karl Borch [1974, p. 128], this theory starts with an additive

[6] During the Conference I learned about the Mutual Assurance Society of Virginia, which was founded in 1784, and about the Mutual Assurance Company of Philadelphia (founded in 1784). In their Festschrift "Founded on Benevolence, A Bicentennial History of the Mutual Assurance Society of Virgina", it is written that William Frederick Ast, a Prussian émigré, initiated the idea based on a system introduced by Frederick the Great.

[7] Here, I follow Eisen [2021].

principle of premium calculation.[8] Both concepts or theories are identical if and only if certain assumptions are met.

First, if the total income in all states is the same, then the prices of the Arrow certificates are proportional to the probabilities of occurrence of each state. Also in this case, the total loss is known, so determining the adequate reserves (and the risk loading) is not an issue. Second, suppose there are n consumer-agents with identical preferences, incomes and expected losses. Then every individual has utility $U(.)$, income $y_i(s) = y$ (with $s = 1, \ldots, m$ representing the states of nature) in the no-loss state, and income $y_i(s) = y - x$ in the loss state. The probability of loss is $\pi_i = \pi$. If the losses are independent, then there are 2^m "natural states", but only $m + 1$ states with different incomes, and the probabilities of these states are

$$\pi(m)_b = \binom{m}{b}\pi^b(1-\pi)^{m-b}, \tag{1}$$

where b is the number of losses. Free trade with contingent claims (or Arrow certificates, "ideal" insurance policies) results in

$$y_i(s) = y - \frac{b(s)x}{n}, \tag{2}$$

where $b(s)x$ is the number of losses of magnitude x in state s, divided by the number of consumer-agents n. This equation shows that the individual income y_i depends on the total income y and the total loss $(b(s)x)$ divided by the number of agents in the group!

If there exists a system of normal risk-transfer contracts, then every insured pays a premium equal to the expected loss (πx) plus a loading (λ_n). There may now be a part of society (r) that insures the rest of society $(1 - r)$; the consumption of this group is $y_i(s) = y - \pi x - \lambda_n$, with certainty. The "insurers" then allocate the risk equally between them, obtaining a contingent consumption or income of

$$y_i(s) = y - \left(\frac{bn}{r}\right)x + \left(\frac{1-r}{r}\right)\pi x + \left(\frac{1-r}{r}\right)\lambda_n \tag{3}$$

This equation demonstrates that the random income of the "insurers" is equal to the total income minus the sum of the losses plus the income from the premiums they received from the insured group (r).

The "cost of inefficiency" per insured individual is then simply the difference between the utility under the conditional claims mechanism multiplied by the number of agents (i.e. the probability of this event) and the utility under a risk-transfer contract,

$$L_n = \Sigma_b\, \pi(n)_b U\left(y - \frac{b(s)x}{n}\right) - U(y - \pi x - \lambda_n) \tag{4}$$

[8] The most widely known are the variance principle for the normal distribution, which is given by $p(f(x)) = E(x) + p\sigma^2$, and for the Poisson distribution one arrives at $p(F(x)) = A.E(x)$, where A is a constant, $E(x)$ is the mean, and p is the price of the distribution.

As Arrow and Lind demonstrated [1970], λ_n and consequently L_n tend to zero if n increases indefinitely.

Consequently, given the law of large numbers, even actuarially calculated insurance premiums do not hinder efficiency. However, and this is the central point here, many types of risk are dependent or correlated, and therefore, the law of large numbers does not apply to them!

To clarify this point, the *reserve theory* and the chosen *premium calculation principle* are based on a list of "insurability criteria", formulated e.g. by Baruch Berliner [1982]. The most important criteria are randomness, the independence of individual risks, the magnitude of risks, and the fact that the premium or price of insurance should be adequate and affordable, while the capacity of the (re)insurance industry must be sufficient (see Table 1)! However, none of these criteria are fulfilled when talking about climate change and the environmental risks and damages involved. In other words, the boundaries of insurability must be expanded, or more sophisticated insurance products must be developed.

Table 1. Insurability criteria

No.	Category	Criterion	Characteristic
1	*actuarial*	*risk/uncertainty*	*measurable*
2		loss occurrences	independent
3		maximum loss	manageable
4		average loss	moderate
5		loss frequency	high
6		moral hazard/adverse selection	not excessive
7	*market determined*	*insurance premium*	*adequate, affordable*
8		insurance cover limits	acceptable
9		industry capacity	sufficient
10	*societal*	*public policy*	*consistent with cover*
11		legal system	permits the cover

Source: Berliner [1982]; Swiss Re [2011].

Practical use of the principle of mutuality: climate change

The already visible consequences

As described in the *Introduction*, climate change is characterised by two unique features. On the one hand, there are the heavy burdens of the choice of the interest rate at which to discount the effects of the distant future – events are occurring today, but the most severe problems will arise in the distant future. This means that the aforementioned time constraint is also at play here. The second unique feature of climate change is the deep structural uncertainties coupled with the unknown technological means to cope with the environmental damages, and our economic inability to meaningfully evaluate the catastrophic losses. Ultimately, this leads to a probability distribution function (which is not normal, but) with very fat tails, such that "its variance is effectively infinite" [Weitzman, 2009, p. 8]. "Fat tails" means that there "is a race in the extreme tail between how rapidly probabilities are declining and how rapidly damages are increasing" [Weitzman, 2009, p. 1].

Some of the consequences and costs are already visible. For example, the costs of the "delayed energy transition" – the shift from fossil energy sources towards renewable ("green") energy – have reached dimensions that Scrooge McDuck could only dream about, as Claudia Kempfert [2023, p. 241] put it. In Germany, the government developed three "rescue packages" and spent more than EUR 300 billion. And this money is not going towards investments for the future but is being "depleted" or is literally being "burnt" [Kempfert, 2023, p. 241]. The increased public debt must somehow be repaid by future generations – in addition to the damages they will inherit caused by fossil fuels. These damages are visible in the form of record-breaking heat waves, droughts or floods (floods and droughts are two sides of the same coin), extreme rainfalls, hails, wildfires, tropical storms and hurricanes.[9] The EEA (European Environment Agency) estimates that the total economic losses caused by extreme weather events in the 32 member states between 1980 and 2020 amounted to approximately EUR 520 billion, whereby around 3% of all events were responsible for 60% of economic losses. Globally, around EUR 277 billion is spent annually to address the consequences of climate change, according to Swiss Re [2023]. "By 2050, climate change will place immense strain on global healthcare systems, causing 14.5 million deaths and $ 12.5 trillion in economic losses", reads the headline of the Executive Summary of the WEF Insight Report on "Quantifying the Impact of Climate Change on Human Health" [2024]. Furthermore, by 2050 we must expect up to 1.2 million climate refugees.

Insurance-Linked Securities (ILS) and mutual insurance as solutions

Given that there are "cascades of great uncertainty", huge amounts of money at stake, almost countless deaths, and certainly no normal distribution – where the discount rate for the future is nearly zero or even negative[10] in the long term – the solutions preferred by economists are difficult, if not impossible, to realise. The existing European Union Emissions Trading System (EU ETS) would require a profound reform, so that the price of a certificate at least partially reflects the "true costs" [Willner, Perino, 2022]. The same is true for insurance economics, as also here a "traditional" insurance contract is not applicable, as shown by the discussion on the insurability criteria above (see Table 1). This means that – as the Süddeutsche Zeitung (2023) once put it – "Climate Change is not insurable".

[9] In a very dramatic "Opinion", David Wallace-Wells [NYT, 9 July 2025, p. 3] remarked – using the examples of Texas, Spain, Brazil – that "longstanding science…suggests that in a warming world the frequency of extreme events at the long end of the distribution tail will increase far more than annual averages."

[10] And not at 5% as assumed in the famous Stern-Report [2007]!

As mentioned earlier, the less one does today, the greater the risks and the likely damage caused by climate change ("fat tails")! And the damages could be severe enough to exceed the insurer's capital or to overwhelm – or even wipe out – the whole insurance industry. Here, as elsewhere, one has to think about new alternatives in risk policy or risk management, and more sophisticated insurance products are needed. One such alternative or new instrument is "securitisation" and the Alternative Risk Transfer (ART) mechanism, where risks are directly transferred to capital markets, which deal with such amounts on a daily basis [Zweifel, Eisen, Eckles, 2021, p. 2921].

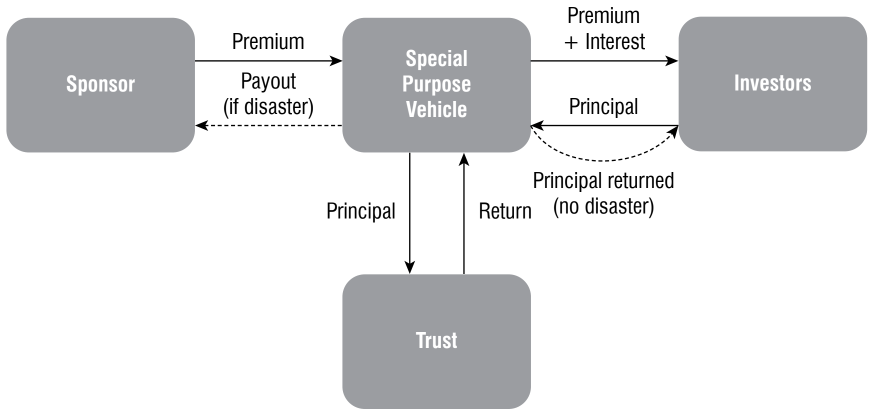
Following the devastating damage caused by Hurricane Andrew, which struck Florida in 1992, catastrophe-linked capital market instruments emerged. This event demonstrated that there was an insufficient supply of (re) insurance to cover this catastrophe risk. To circumvent these capacity constraints in traditional (re) insurance markets, remarkable innovations were developed: *Insurance-linked Securities* (ILS) and, in particular, *catastrophe (CAT) bonds.*

"The case for ILS strengthened in the wake of the heavy hurricane season of 2005, when Hurricanes Katrina, Rita, Wilma, Ophelia and Dennis contributed to a record USD 80 billion in insured losses", as reported by Swiss Re [2011, p. 7]. The market for ILS recorded a remarkable year-on-year growth of 10.5%. According to AON (2025), alternative capital exceeded USD 21 billion – a record high – and the total outstanding CAT bond volume had reached a record USD 55 billion by the end of June 2025. The average transaction size increased to USD 300 million. The AON Report [2025] also shows that CAT bonds generated a return of 14.1% for investors over the 12-month period (ending June 2025), measured by the AON Securities Catastrophe Bond Total Return Index.

The general mechanism of CAT bonds[11] is shown in Figure 1. It involves three parties: a sponsor (cedent, (re) insurer) seeks to remove a catastrophe risk from its balance sheet. To this end, it sets up a bankruptcy-remote Special Purpose Vehicle (SPV), which issues the CAT bond to capital market investors (typically large institutional buyers). The SPV invests the investors' principal in highly-rated securities (e.g. Treasury bonds) held in a collateral trust. The investors receive a steady stream of variable interest payments with low interest rate risk. The CAT bond compensates the investors for bearing the disaster risk with premium payments from the sponsor. If the pre-defined specific catastrophe event (storm, wildfire, earthquake) occurs during the bond's term (typically one to four years), the SPV transfers all or part of the principal to the sponsor for post-catastrophe recovery, and investors may lose part or all of their principal. If the bond expires without the event occurring, the principal is returned to investors [Braun, Kousky, 2021]. In other words, CAT bonds function like fully-collateralised multi-year reinsurance contracts!

[11] For a short and concise introduction see Braun, Kousky [2021]; for more details see Cummins, Barrieu [2013] and Barrieu, Braun, Makariou [2025].

Figure 1. CAT bonds payment structure



Source: Braun, Kousky [2021, p. 2].

To calculate catastrophe risk and the premium resulting from the combination of the hazard type and the region, (re) insurers use specialised modelling firms. The most interesting element here is the trigger, which determines whether the principal amount is paid out to the sponsor or whether the catastrophe qualifies for coverage! Typically, four types of triggers are used [Braun, Kousky, 2021; Swiss Re, 2011]: Indemnity loss, industry loss index, parametric or parametric index, and modelled loss triggers; of these, almost 70% of the CAT bond market use indemnity triggers, and about 20% use industry loss triggers [Figure 2 in Braun, Kousky, 2021, p. 4]. While parametric triggers (a measurable characteristic of the covered catastrophe, e.g. earthquake magnitude or hurricane wind speed) are highly transparent and allow for a fast payout, "the underlying physical parameters will not be perfectly correlated with insurance losses, [so] this trigger type exhibits a substantial basis loss for sponsors" [Braun, Kousky, 2021, p. 4]. Indemnity triggers are quite the opposite: very little transparency for investors, even with moral hazard on their side, no basis risk – in other words, they represent full protection with a long settlement period!

Indemnity and industry loss triggers only take individual or industry-wide insured losses into account, but not the total economic loss. This means that the "protection gap" between insured and overall economic losses caused by natural disasters must be closed; otherwise:[12] as reported by Swiss Re [2026], the share of insured losses increased from 15% in 1976–1985 to 30% in 1996–2005 and over 40% in 2018–2025, though with a significant difference between industrialised and emerging economies!

[12] Take, for example, the total economic losses for Jamaica caused by Hurricane Melissa, a category 5 storm, which made landfall in October 2025 with sustained winds near 300 km/h. It was Jamaica's strongest hurricane on record and produced the highest insured losses in Jamaca's history, up to USD 2.5 billion, of which the country received USD 91.9 million from the CCRIF, and a further USD 150 million from the country's World Bank-supported Cat bond within days after the disaster. The total economic losses, however, were about USD 8.8 billion, well above the insured losses [Swiss Re, 2026]. Therefore, the "protection gap" of this event is around USD 6.3 billion, more than double the insured loss! (CCRIF = Caribbean Catastrophe Risk Insurance Facility, which allows CARICOM governments to purchase insurance coverage to finance immediate post-disaster relief, as reported by Stahel, 2009).

The other triggers are also "limited", because they use "known techniques to evaluate or model risks". Furthermore, losses must be attributable to identifiable causes and be verifiable in order to limit moral hazard and adverse selection in the ILS market.

It is interesting to note that, while the non-life section of the ILS market is very visible, largely due to CAT bonds, the life section is – according to Cummins and Barrieu [2013, p. 587] – "larger in terms of outstanding volume of securities". While there are different motivations in the life section, Catastrophe mortality bonds, which cover only a small part of this section, are the most comparable with non-life ILS. Relevant here are the consequences of a pandemic (see the recent COVID-19 pandemic[13]) or mortality spikes due to major natural disasters, such as Hurricane Katarina with 1,836 fatalities, or the Tohoku earthquake (followed by a tsunami) with 18,451 fatalities (in March 2011) [Swiss Re, 2018]. Also covered are spikes in health care utilisation, as well as trends in mortality improvements, the so-called longevity risk. The trigger (for Swiss Re Vita Capital Ltd and Swiss Re's Kortis Capital Ltd) is based on a calculated Mortality Index Value and on the Longevity Divergence Index, which measures the difference in the rate of mortality improvement between two different age groups of two different regions [Swiss Re, 2011, p. 32].

As shown, the (re) insurance industry has begun to offer dedicated solutions via the use of ILS, and in particular CAT bonds, also to address environmental risks.[14] However, their function is limited, they operate (merely) as fully collateralised multi-year reinsurance contracts!

To close the "protection gap" and the "technology gap", the *theory of mutual insurance* comes into play, which is particularly relevant when – as demonstrated here – the risks are large, the probabilities are uncertain or unknown, and the events are correlated. In Eisen [2021], I highlight the practical use of mutual insurance using three examples: unknown or unpredictable risks; correlated risks, and macroeconomic risks (demographic risks in particular). It was G. Skogh [1998] who pointed out that the theory of mutuality is particularly useful if the assignment of probabilities is impossible or very uncertain, so that in "normal" insurance contracts the loading is very high, making insurance contracts very costly. A similar picture emerges with macroeconomic or demographic risks. Here the "demographic waves", i.e. the great "baby boom cohort" followed by a small "pill break generation" [Börsch-Supan, 1999], cannot be eliminated through traditional portfolio or hedging strategies, which only deliver "cross-sectional risk sharing", meaning a risk exchange between agents who live at a fixed point in time. These demographic changes require intertemporal risk smoothing, either via

[13] The AON ILS Annual Report 2021 states [p. 17] that during the COVID-19 pandemic "the insurance industry was faced with enormous challenges…from COVID-19 related incidents, increased replacement costs due to a disrupted supply chain…However, the re/insurance industry managed to weather the storm successfully". Nevertheless, these "connected extremes" will "provide critical learning opportunities" and the year 2020 "also highlighted topics such as the protection gap to address the underserved, increasingly vulnerable populations…and the growing influence from climate change".

[14] An interesting example is offered by Bank of America, which issued in 2020 a USD 1 billion ESG bond to provide loans to not-for-profit hospitals, skilled nursing facilities, and manufacturers of healthcare equipment supplies; https://newsroom.bankofamerica.com/press-release/corporate-and-financial-news/bank-of-america-issues-1-billion-corporate-social-bond (accessed: 10.07.2024).

a very high and very costly capital stock, or via intertemporal risk allocation, which can only be achieved by a collective social security system, a (large) mutual insurance mechanism, or the state, both of which can newly allocate or reallocate such risks.

Correlated risks are the third example that I would like to stress here. All the examples of environment-related risks mentioned are highly correlated. New industrial risks, development risks, risks associated with new drugs or new vaccines, nanotechnologies, and AI-related risks are also virtually uninsurable or insured only to a limited extent. Even when correlation for certain risk types is relatively low, the inflationary effects are strongly correlated [Eisen, 2021, p. 229]. Therefore, the optimal risk allocation contract (or mechanism) is one in which the risks are separated into a diversifiable and a non-diversifiable portion. The diversifiable portion can be fully insured, while the non-diversifiable portion cannot be insured at all or can only be insured partially. "*This is the essence of mutual insurance*", as summarised by Doherty and Schlesinger [2002, p. 46, italics added by RE].

A similar approach can be found in the public-private insurance model developed by Perazzini, Gnecco and Pammolli [2024] for earthquakes and floods in Italy, in which the government and an insurer cooperate in risk-financing. The interesting finding is that "when not supported by the government, private insurance might either financially over-expose the insurer or set premiums so high that individuals would fail to purchase policies". Furthermore, the authors note that "the burden on public capitals" is alleviated by "lowering the amount of capitals required and by keeping the probability of additional capital injections into the insurance reserves relatively low" [Perazzini, Gnecco, Pammolli, 2024, p. 225]. This means that, besides the public sector, private sector financing may be crucial due to its various capital sources.

The individual risks are fully insured, but an additional payment ("Nachschuss" or reimbursement) to (from) the insurer has to be paid (or will be paid) according to the total loss of the insurance pool! In the model of Doherty and Schlesinger [2002, p. 47], the agents can determine the degree of participation (or coverage) of the total loss (or of the non-diversifiable part) themselves. Without going into the mathematical details, the following results should be noted. Let me summarise them in ***Thesis 2***:

> *If the market risk premium is the same for the systematic risk, regardless of whether traded on a futures or an insurance market, the mutual insurance market offers the same set of alternatives and optimal solutions as would be expected on two separate markets – namely an insurance market and a capital market!*

Summary: climate change and mutual insurance

This study proposes a novel solution or framework for addressing environmental-related risks and losses. As pointed out already by Göran Skogh [1999], collective solutions are necessary when risks or losses are interdependent and of a very large scale. This applies in particular to long-run risks such as damages from environmental or climate changes. To smooth these risks over time, these long-term risks require either a massive capital stock – with all the well-known problems [Orszag, Stiglitz, 2001] – or intergenerational distribution. Only the State can reallocate or redistribute such risks (or social insurance) – or the alternative proposed here: *Mutual Insurance*!

To address the dynamic trends of growing dimensions in natural disasters and damage caused by climate change, the *principles of mutual insurance* must be emphasised. Since the aforementioned criteria for insurability are not met, and the existing insurance markets are neither perfect nor complete,[15] there are also "practical arguments" in favour of mutual insurance. In particular, I have shown that for long-run risks and risks with a high degree of uncertainty, the advantages of mutual insurance are obvious! Furthermore, the use of mutual insurance not only provides for financing, but also offers incentives to members to reduce risks, mitigate losses, and make disaster provisions. However, this does not mean that there are no roles for traditional (re)insurance companies, as argued in several reports by the Geneva Association.[16] Nonetheless, the capacity constraints mentioned above, as well as the informational and technological challenges in the capital and ILS markets, support the arguments put forth here.

Despite my enthusiasm for the *theory of mutual insurance*, there are two open questions to which I have not yet found satisfactory answers [Eisen, 2021, p. 233]. Firstly, is the alternative of using two markets – the insurance market for the diversifiable part of the risks and the capital market for the non-diversifiable portion – more cost-effective than the "participatory" mutual contract?[17] Secondly, one should take into account that also members of the State or mutual insurance organisation are risk-averse, and therefore may prefer the more expensive traditional risk allocation mechanism (via the fixed insurance premium paid in advance or *ex ante*), and shy away from the risk of a (potentially very high) additional payment *ex post*.[18]

References

1. Albrecht, P., Huggenberger, M. (2017). The Fundamental Theorem of Mutual Insurance, *Insurance: Mathematics and Economics*, 75, pp. 180–188. DOI: 10.1016/j.insmatheco.2017.06.002.
2. AON. (2021). *ILS Annual Report 2021*.
3. AON. (2025). *ILS Annual Report 2025*.
4. Arrow, K.J. (1970). *Essays in the Theory of Risk Bearing*. Amsterdam and London: North-Holland.

[15] See Eisen [2004].

[16] See, for example, GA [2024a; 2024b] or even as early as GA [2009].

[17] As noted by Froot [2001], one should take into account that different transaction costs are involved with different risk allocation mechanisms!

[18] In a mathematical context this question is discussed by Albrecht and Huggenberger [2017].

5. Bank of America (2020). *Bank of America Issues $1 Billion Corporate Social Bond* [Press release], https://newsroom.bankofamerica.com/press-release/corporate-and-financial-news/bank-of-america-issues-1-billion-corporate-social-bond (accessed: 18.05.2026).
6. Barrieu, P., Braun, A., Makariou, D. (2025). Catastrophe Bonds. In: *Handbook of Insurance* (pp. 169–195), G. Dionne (Ed.). Cham: Springer.
7. Berliner, B. (1982). *Limits of Insurability of Risks*. Englewood Cliffs: Prentice Hall.
8. Börsch-Supan, A. (1999). Demographie, Entwicklung und Stabilität der Sozialversicherung in Deutschland, *Allgemeines Statistisches Archiv*, 83(1), pp. 27–44.
9. Braun, A., Kousky, C. (2021). *Catastrophe Bonds*. Philadelphia: Wharton Risk Center.
10. Cummins, J.D., Barrieu, P. (2013). Innovations in Insurance Markets: Hybrid and Securitized Risk-Transfer Solutions. In: *Handbook of Insurance* (pp. 547–602), G. Dionne (Ed.). New York: Springer.
11. Doherty, N.A. (1984). Portfolio Efficient Insurance Buying Strategies, *Journal of Risk and Insurance*, 51(2), pp. 205–224. DOI: 10.2307/252554.
12. Doherty, N.A., Schlesinger, H. (2002). Insurance Contracts and Securitization, *Journal of Risk and Insurance*, 69(1), pp. 45–62. DOI: 10.1111/1539-6975.00004.
13. Eisen, R. (2004). Incomplete Markets. In: *Encyclopaedia of Actuarial Science* (pp. 883–886), J.L. Teugels, B. Sundt (Eds.). Chichester: Wiley.
14. Eisen, R. (2021). Vulnerability and Mutual Insurance, *The Geneva Papers on Risk and Insurance – Issues and Practice*, 46(2), pp. 224–235. DOI: 10.1057/s41288-021-00217-7.
15. European Environment Agency (2022). *Economic Losses and Fatalities From Weather- and Climate-Related Events in Europe*. Briefing No. 21/2022.
16. Froot, K.A. (2001). The Market for Catastrophe Risk: A Clinical Examination, *Journal of Financial Economics*, 60(2–3), pp. 529–571. DOI: 10.1016/S0304-405X(01)00052-6.
17. Geneva Association (2009). *The Insurance Industry and Climate Change – Contribution to the Global Debate*, https://www.genevaassociation.org/sites/default/files/2009_geneva_report_2_the_insurance_industry_and_climate_change_-_contribution_to_the_global_debate_0.pdf (accessed: 18.05.2026).
18. Geneva Association (2024a). *Climate Tech for Industrial Decarbonisation: What Role for Insurers?*, https://www.genevaassociation.org/sites/default/files/2024-01/climate_tech_full_report.pdf (accessed: 18.05.2026).
19. Geneva Association (2024b). *Bringing Climate Tech to Market: The Powerful Role of Insurance*, https://www.genevaassociation.org/sites/default/files/2024-04/climate_tech_2_report_090424_web_.pdf (accessed: 18.05.2026).
20. Gollier, Ch. (2013). *Pricing the Planet's Future: The Economics of Discounting in an Uncertain World,* Princeton and Oxford: PUP.
21. Grágás (2006). In: *Wikipedia*, https://de.wikipedia.org/w/index.php?title=Gr%C3%A1g%C3%A1s&oldid=252174822 (accessed: 18.05.2026).
22. Gray Goose Laws (2005). In: *Wikipedia*, https://en.wikipedia.org/w/index.php? title=Gray_Goose_Laws&oldid=1348771338 (accessed: 18.05.2026).
23. Karten, W. (1993). *Das Einzelrisiko und seine Kalkulation*. Wiesbaden: Springer.

24. Kempfert, C. (2023). *Schockwellen*. Frankfurt a. M. and New York: Campus.
25. Mahr, W. (1951). *Einführung in die Versicherungswirtschaft – Allgemeine Versicherungslehre*. Berlin: Duncker & Humblot.
26. Marshall, J.M. (1974). Insurance as a Market in Contingent Claims: Structure and Performance, *Bell Journal of Economics*, 5(2), pp. 670–682.
27. Nordhaus, W.D. (2007). A Review of the Stern Review on the Economics of Climate Change, *Journal of Economic Literature*, 45(3), pp. 686–702. DOI: 10.1257/jel.45.3.686.
28. Orszag, P.R., Stiglitz, J.E. (2001). Rethinking Pension Reform: Ten Myths about Social Security Systems. In: *New Ideas about Old Age Security: Toward Sustainable Pension Systems in the 21st Century* (pp. 17–56), E. Holzmann, J.E. Stiglitz (Eds.). Washington, D.C.: The World Bank.
29. Perazzini, S., Gnecco, G., Pammolli, F. (2024). A Public-Private Insurance Model for Disaster Risk Management: An Application to Italy, *Italian Economic Journal*, 10(1), pp. 225–267. DOI: 10.1007/s40797-022-00210-6.
30. Skogh, G. (1999). Risk-Sharing Institutions for Unpredictable Losses, *Journal of Institutional and Theoretical Economics*, 155(3), pp. 505–515.
31. Stahel, W.R. (2009). Risk Management, Insurance and Climate Change, *Risk Management*, 46, pp. 1–3.
32. Stern, N. (2007). *The Economics of Climate Change – The Stern Review*, Cambridge: Cambridge UP.
33. Swiss Re (2011). *The Fundamentals of Insurance-Linked Securities*, https://www.institutdesactuaires.com/global/gene/link.php?doc_id=871&fg=1 (accessed: 18.05.2026).
34. Swiss Re (2018). *Natural Catastrophes and Man-Made Disasters in 2017: A Year of Record-Breaking Losses*, https://www.swissre.com/dam/jcr:1b3e94c3-ac4e-4585-aa6f-4d482d8f46cc/sigma1_2018_en.pdf (accessed: 18.05.2026).
35. Swiss Re (2023). *Severe Thunderstorms Account for up to 70% of all Insured Natural Catastrophe Losses in First Half of 2023*, https://www.swissre.com/press-release/Severe-thunderstorms-account-for-up-to-70-of-all-insured-natural-catastrophe-losses-in-first-half-of-2023-Swiss-Re-Institute-estimates/cea79f3c-6486-41a8-9c6e-09df260efe30 (accessed: 06.09.2023).
36. Swiss Re (2026). *Natural Catastrophes in 2025: The Persistent Rise of Wildfire and Storm Risk*, https://www.swissre.com/dam/jcr:4b5669a3-b7e2-4682-bf96-a597085958a6/sigma-1-2026-natural-catastrophes-report.pdf (accessed: 18.05.2026).
37. SZ (Süddeutsche Zeitung) (2023). Der Klimawandel ist nicht versicherbar; Interview mit Avinash Persaud, *Süddeutsche Zeitung*, 282, p. 6.
38. Venezian, E.C. (1983). Risk, Return, and Rate Regulation in Property and Liability Insurance, *Journal of Insurance Regulation*, 2(1), pp. 98–124.
39. Weitzman, M.L. (2009). Additive Damages, Fat-Tailed Climate Dynamics, and Uncertain Discounting, *Economics – The Open Access, Open-Assessment E-Journal*, 3, pp. 1–29. DOI: 10.5018/economics-ejournal.ja.2009-39.
40. Willett, A.H. (1901). *The Economic Theory of Risk and Insurance*. Republished by S.S. Huebner Foundation for Insurance Education. Homewood: Irwin Publ.

41. Willner, M., Perino, G. (2022). Beyond Control: Policy Incoherence of the EU Emissions Trading System, *Politics and Governance*, 10(1), pp. 256–264. DOI: 10.17645/pag.v10i1.4797.
42. World Economic Forum (2024). *Quantifying the Impact of Climate Change on Human Health*. (Insight Report, in collaboration with Oliver Wyman), https://www3.weforum.org/docs/WEF_Quantifying_the_Impact_of_Climate_Change_on_Human_Health_2024.pdf (accessed: 18.05.2026).
43. Zweifel, P., Eisen, R., Eckles, D.L. (2021). *Insurance Economics*, 2nd ed. Cham: Springer.