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Strengthening Resilience and Sustainability for Post-Disaster Recovery: A Comparative Law and Economics Analysis on Smart Mixes Between Mechanisms

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Abstract: This article advocates smart mixes of mechanisms of post-disaster recovery in terms of boosting resilience and sustainability through liability rules, government intervention, insurance, and their combinations. Liability rules can provide compensation to victims and, in theory, also reduce disaster risks, while they have their limits in practice. The government widely intervenes in disaster compensation in many countries, but it faces challenges in how it can intervene fairly and efficiently, whether through informal channels, such as ad hoc charity, or structured approaches, such as compensation funds. As governments may struggle to provide efficient and effective compensation ex post, insurance may offer proactive solutions with models of first-party catastrophe insurance and third-party liability insurance ex ante. Where market failure, liability failure, and government failure may all arise, a smart mix of mechanisms is often preferable from a law and economic perspective, rather than relying solely on one framework. However, upon examining empirical evidence regarding the effectiveness of these instruments in China, the UK, France, Germany, and Turkey, it becomes apparent that a mix of mechanisms is not always applied in an effective manner. Models of mandatory comprehensive disaster insurance, and Public–Private Partnership (PPP), which both receive government intervention as a last resort to the market and liability failures, can reach the goal of more effective compensation for disaster victims, risk prevention and resilience when faced with disaster recovery, and should therefore be substantially implemented beyond the current levels. To be clear, the proposed mix of solutions mainly focuses on legal and economic dimensions which are rather limited, ignoring, for example, building codes for structures and physical interventions.

Keywords: post-disaster recovery; resilience; liability rule; government intervention; disaster insurance; smart mixes; mandatory insurance; public-private partnership

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1. Introduction

As one of the most critical issues confronting the world, climate change and the resulting extreme weather-related disasters have started to wreak havoc globally. For example, hurricanes and floods are hitting India, Germany, US, China, and many other countries with rising frequency; more frequent wildfires ravage Canada, Australia, and the western regions of the United States; extreme heatwaves drive the UK and the US to declare a national emergency; and the rising sea levels pose a threat to coastal communities and islands in the Pacific Ocean, exacerbating the severity of particular weather events [1]. Climate change, coupled with the growing concentration of the global population and assets in high-risk areas, suggests that climate-related disasters are likely to become increasingly frequent, intense, and expensive in the coming years. Data show that there is a marked

increase in the amount of losses from insured catastrophes worldwide, in which the insured losses have grown by 5–7% on an average annual basis since 1992 [2].

Resilience has become a central concept in theoretical research and practical disaster management [3]. Theoretical studies use it "to describe the ability of a system to return quickly to its initial state of equilibrium following a disturbance generated by an external phenomenon" [4]. In legal and policy documents, for example, in the United Nations' Hyogo Framework for Action, it is defined as "The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure" [5]. It is also defined by the Intergovernmental Panel on Climate Change (IPCC) as "The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions [6]". In this paper, the concept of resilience also needs to be placed in a context of global risk and resilience frameworks (e.g., UN, IPCC); we try to provide some links with them and then define resilience simply as the capacity of a social unit to rebound after a crisis, and/or the ability to self-organize during such a crisis [7]. It encompasses two aspects: the innate capability of an entity to endure stress and shock, and its ability to recover and rebound from the consequent impact [8]. Therefore, within the framework of this paper, a resilient post-disaster recovery system should ideally achieve two objectives: (1) to be economically efficient by which we mean to offer sufficient incentives for disaster risk reduction, and (2) legal justice, which means to ensure that there is adequate compensation for disaster victims and "no one is left behind or pushed behind" [9], thus creating resilience for a society facing systemic risks [10].

The crucial question is, however, what kind of instruments can boost resilience of post-disaster recovery in a manner to achieve economic efficiency and legal justice. The main objective of this paper is thus to investigate the most efficient instruments and the most effective regulatory and policy measures to improve the adaptive capacity of and enhance resilience for post-disaster recovery. We do so by critically discussing the advantages and disadvantages of liability rules, government compensation, and insurance in achieving a resilient post-disaster recovery, and then present examples from the way in which the various instruments are used in different legal systems, showing that they present both market and government failures. To be clear, the analysis in this paper is limited to the way in which financial instruments can deal with direct economic losses resulting from disasters. We do recognize that the concept of resilience is, when applied to post-disaster recovery, a broad concept covering other aspects (for example on how to reconstruct the built environment) that will not be addressed in this paper. There is a rich literature on disaster recovery addressing the challenges of resilience [11]. The original contribution of this article is that it, first of all, examines how legal and policy instruments aiming at compensations of victims can boost post-disaster resilience. In addition, the article provides a critical analysis of three specific instruments (liability rules, government intervention, and insurance) on the basis of clear criteria (ability to provide compensation and prevention). And third, the article uses case studies to show that many jurisdictions rely strongly on one particular mechanism (often either government compensation or insurance), whereas we argue that the goals of a resilient post-disaster recovery system can best be achieved through a combination of various instruments. That is the final contribution of our article: we point out the importance of searching for a so-called smart mix of the three instruments (liability rules, government compensation and insurance) to contribute to a resilient post-disaster recovery.

2. Literature Review and Theoretical Background

Scholars across different theoretical frameworks have suggested that three typical types of instruments for disaster compensation and post-disaster reconstruction are distinguished [12,13]. The type of instrument depends strongly upon the nature of the disaster.

In that respect, a distinction is made between, on the one hand, natural disasters (such as flooding, volcanic eruptions or earthquakes) where a natural phenomenon is the cause of the disaster and, on the other hand, man-made or technological disasters where human intervention is the source of the disaster. A third type of disaster is the hybrid one, which has both a natural origin and the influence of human activity. One example is flooding, which is a natural phenomenon but can lead to a disaster if people decided to build in flood-prone areas. Another is where a natural phenomenon (like bad weather events such as hurricanes) can be triggered through the intervention of human activity. The latter is, of course, typical with climate-related disasters that also have an anthropogenic component and are, therefore, surely not solely "natural" but hybrid at best. This distinction is also of relevance for the choice of instruments for disaster compensation. A first instrument involves liability rules, particularly applicable to victims of technological disasters where an accountable party can be determined. The second type pertains to government intervention, which may include (a) financial measures, such as ad hoc charity, bailouts, or funds allocated from taxpayer money, (b) administrative measures, such as monitoring and early warning systems for natural disasters, meta-planning for disruptive events and zoning for building codes and standards, and (c) physical measures, such as dikes and levees for disaster risk reduction [14,15]. The third type concerns insurance coverage, typically comprising first-party insurance for victims of natural disasters and third-party insurance for those affected by technological disasters.

We acknowledge that liability rules, government intervention, and insurance can all contribute to recovery as well as to preparation and have a positive effect on post-disaster recovery in terms of boosting resilience. Meanwhile, we have to face a number of failures of the market, the liability system, and the government. Starting with the liability system, in natural disaster scenarios, no tortfeasor is at hand and victims therefore barely can refer to liability rules to seek compensation. Victims therefore often turn to the government for compensation. That mechanism is, however, criticized for incentivizing insufficient ex ante investments in prevention and for an excessive provision of ex post compensation, thus resulting in government failure. Politicians, indeed, frequently compete to allocate recovery funds after disasters, motivated by substantial political benefits [16]. For example, after the 2005 Katrina hurricane, the U.S. federal government was unprepared, but spent an overall sum of USD 88 billion "to the response, recovery and rebuilding efforts" [17]. Increasingly, therefore, market-based instruments (often referred to as incentive instruments) have been promoted, the most important one in this context being insurance. Economists have strongly contended that insurance can incentivize an operator to internalize externalities at minimal expense [18]. In practice, however, the promotion of insurance to cover the risks of catastrophic disasters faces a number of challenges on both the supply and demand sides, such as insurability and capacity barriers, in nearly every country. Hence, insurance may fail market failures resulting in insufficient protection to boost post-disaster resilience. The limitations of each of those specific instruments will be made clear throughout the paper and in presenting the case studies which illustrate the specific market and regulatory failures.

In this paper, after discussing the pros and cons of the instruments individually, we try to explore how they can contribute to disaster compensation and prevention and to advocate combinations of instruments as the preferred policy approach. In other words, we rely on insights from economics [19] arguing that a combination of private, market-based instruments (such as liability rules and insurance) should be combined with government intervention to remedy externalities generally [20]. Such a smart mix of different instruments [21] can address the adverse impacts of imperfect information, private interests, ineffectiveness, and inaccuracies in measurement, and could play a crucial role in incentivizing and guiding stakeholders' preferences towards resilience.

3. Methodology

First, with the application of a law and economic study which aims at identifying victim compensation with minimal cost while incentivizing disaster risk reduction, our

study will demonstrate how a smart combination of mechanisms offers effective incentives for prevention and mitigation at minimal expense. Consequently, this approach facilitates welfare maximization, as the law and economics methodology critically evaluates various instruments for post-disaster recovery [22]. The advantage of this economics approach to legal instruments is that it allows us to verify the way in which the different instruments affect the incentives of the stakeholders involved, more particularly, as far as prevention is concerned. However, the traditional law and economics approach has the limitation of being based on the assumption of rational choice theory. The decisions concerning disaster preparedness are often not rational and subject to a variety of biases [23]. For that reason, we extend the analysis with behavioral law and economics to investigate anomalies in people's disaster-response decisions, such as the lack of demand for disaster insurance, drawing on theories of individuals' bounded rationality and cognitive biases [24].

Second, even though our paper is mostly theoretical and not based on a collection of data, we do adopt a comparative legal approach. This allows us to examine specific post-disaster recovery mechanisms and to delve into a detailed analysis of regimes across five selected states [14]. The five selected states (China, the UK, France, Germany, and Turkey) were chosen for their representative (including both developed and developing countries) legislative frameworks (or lack thereof), and the thorough discussions at the national level regarding the adequacy of their post-disaster recovery mechanisms. Moreover, these countries also represent different solutions to post-disaster recovery allowing us to conduct a critical comparative analysis of the functioning of the different mechanisms within these specific jurisdictions.

In order to analyze the effectiveness of the (combination of) specific instruments (liability rules, government compensation, and insurance), we rely on two clear criteria: (1) the ability of the mechanism to provide post-disaster recovery (in other words, compensation), and (2) the way in which the mechanism provides incentives to stakeholders to invest in preventive measures. Those preventive measures could either aim at reducing the probability of the disaster (disaster risk reduction) (which will mostly play a role with human-made disasters rather than with natural disasters) and mitigation of damages (in other words, the measures taken to reduce the scope of the damage).

4. Pros and Cons of Liability Rules in Post-Disaster Recovery

4.1. Efficient Liability Rules

This section argues the role of liability rules in protecting property and personal interests and boosting the resilience of post-disaster recovery through two traditional functions, which are prevention (by deterrence) and compensation [25,26]. The deterrent effect of liability rules compel potential tortfeasors to exercise efficient care. Through liability rules, enterprises responsible for specific risks are confronted with the costs of their activities, thereby incentivizing preventative measures. Additionally, the tortfeasor—the party creating the risks—bears the responsibility for compensating victims and facilitating perfect risk diversification. Furthermore, empirical evidence increasingly supports the deterrent effect of liability rules in practice [27]. To be clear, there are also limitations where the model of liability rules is involved. Liability rules can exert their fullest deterrent effect only in cases of technological disasters, where an identifiable tortfeasor is accountable for damage directly attributable to human causes, such as the explosion of a petrochemical factory or a nuclear power plant. Conversely, natural disasters like flooding or hurricanes are often deemed "acts of God" as they lack identifiable tortfeasors. Note that, in theory, liability rules could still play a role in hybrid disasters, such as climate-related disasters that certainly have an anthropogenic component. It is therefore not surprising that, in recent years, the phenomenon of climate change litigation has expanded whereby tort rules are used, either against governments or against emitters to seek a reduction in greenhouse gas emissions [28,29]. Even though there are now some cases where liability rules are used to seek compensation for climate-related harm, most cases still focus on achieving mitigation [28].

Having advocated the significant advantages of employing liability rules, the subsequent inquiry has to determine whether these rules should be structured as strict liability or negligence regimes. The literature suggests compelling arguments favoring a strict liability rule for highly hazardous activities such as operating a nuclear power station. The key advantage of a strict liability rule lies in its ability to transfer all social costs of an accident to the tortfeasor, incentivizing them to conduct an efficient cost-benefit analysis and implement preventive measures [30].

While strict liability can theoretically be effective for addressing technological disasters, it should hence be accompanied by three conditions to avoid the risk of under-deterrence compared to negligence [31]. First, strict liability may only be effective if measures are in place to address the insolvency issue. Insolvency occurs when the amount of damage exceeds the tortfeasor's financial resources, which is highly probable in the case of catastrophes. Therefore, the implementation of strict liability should be paired with measures to prevent insolvency. There is a strong argument for mandating financial coverage, such as liability insurance (as discussed below), for disasters. Otherwise, the "judgment proof problem" may occur, where liability rules might not prove to be effective deterrent [32]. Second, there should likewise be no limits on the liability of the potential wrongdoer. Imposing a financial cap that restricts the tortfeasor's liability to a set amount would yield similar consequences as insolvency, resulting in under-deterrence and thereby undermining incentives for prevention. Third, in the event of multiple wrongdoers, a joint and several liability rule should be implemented. When several tortfeasors have collaborated, liability should be allocated in a manner that holds all parties accountable to the extent of their contribution to the risk, thereby fostering incentives for mutual monitoring among joint tortfeasors.

4.2. Limits of Liability Rules

The limitations of liability rules are underscored in Shavell's seminal work on choosing between liability rules and safety regulation [19]. According to Shavell, regulation is a far more efficient tool for managing externalities, such as damage to buildings, under certain conditions. These conditions include situations where (1) the government possesses better information on preventive technology than private parties, (2) insolvency issues arise, and/or (3) liability suits are unlikely to be initiated for various reasons [19]. When considering potential damage to properties and bodily injuries stemming from technological events, it appears that these potential drawbacks of liability rules are indeed relevant.

First, private entities may lack adequate information about preventive technology in certain instances, while the government, taking advantages of scale, could invest more efficiently in prevention measures. Regulation could also facilitate the dissemination of information to market parties regarding the best prevention technologies.

Second, the insolvency issue will inevitably arise in situations where smaller operators could inflict significant damage, the potential magnitude of which might exceed their personal finances. Furthermore, the limited liability of corporations may encourage the externalization of damage to third parties and society at large [33]. If solvency guarantees are unavailable or insufficient for addressing the under-deterrence resulting from insolvency, this could serve as an additional case for implementing proactive safety regulation. This is not only a theoretical problem. A report concerning environmental liability of companies in the EU indicated that many cases of environmental harm could not be compensated via liability rules because the liable operator did not have sufficient liability insurance coverage, lacked the necessary funds to compensate the damage, and ultimately often went bankrupt [34].

Third, there can be various reasons why tort claims are never pursued, even when all the necessary requirements are theoretically met. In some instances, where tortfeasors cannot be identified, there may be a significant time gap between the incident and the resulting harm (referred to as latency), and issues of proof and uncertainty over causation may arise. Another flaw of liability rules is that victims may encounter significant obstacles, such as difficulties in accessing the court system and effectively litigating their case. Legal

aid, contingency fees, or other mechanisms aimed at lowering barriers to accessing justice are frequently underdeveloped and may not adequately address these hurdles [35].

Due to the significant obstacles faced by victims, the use of liability rules for compensating victims of catastrophes may appear to be ad hoc in nature. In essence, certain individuals may receive substantial compensation if they win the "tort law lottery", while others may receive no compensation at all. Compensation through liability rules, therefore, lacks a systematic framework and may also contradict the principle of equality.

4.3. A Short Summary

In theory, liability rules could serve to prevent damage to populations and properties and provide compensation afterward. In practice, liability rules may function more as an ad hoc system, infrequently applied due to the significant barriers to entering the liability regime. Because of various challenges, such as causation issues, latency periods, burden of proof, and limited access to justice, liability rules may have only a minimal impact or serve merely as a supplementary measure in the prevention of technological disasters.

Furthermore, as previously noted, a significant drawback of liability rules is that they can effectively serve their preventive and compensatory roles primarily in instances of technological disasters where an identifiable wrongdoer is present and the damage can be directly linked to human actions. Regarding natural disasters, liability rules may play a diminished role since no identifiable tortfeasor can typically be found, as is the scenario with phenomena such as earthquakes. In some instances, distinguishing adequately between technological and natural disasters can prove challenging. For example, intense rainfall can result in flooding due to alterations in river courses caused by infrastructure projects, reducing the natural carrying capacity of water. Additionally, governments may have encouraged construction in areas prone to flooding, exacerbating the impact of natural disasters. Conversely, natural catastrophes can subsequently trigger technological disasters, as demonstrated by the tsunami that caused the nuclear disaster in Fukushima [36].

Catastrophes caused by terrorism is another example. On the one hand, events like terrorist attacks are clearly human-made; on the other hand, they share similarities with natural disasters in that the perpetrator (the terrorist) is often unidentifiable or insolvent. Consequently, liability rules may not be applicable in such cases, although this may differ in other human-made disasters such as fires or explosions [37]. Indeed, while terrorist attacks are technically considered human-made, the perpetrators, terrorists, are unlikely to be deterred by the application of liability rules.

The general conclusion of this is that while liability rules can indeed have an impact on protecting properties and bodily interests, they may also have significant limitations. However, some of the limitations of liability rules can also be remedied by facilitating claims by the victims. For example, the problem that liability rules no longer provide a deterrent effect in case of insolvency [32] could be remedied by mandating financial security [38]. Also, the widespread nature of the damage, which could lead to lacking centers for victims to bring a lawsuit [39], could be remedied by either allowing collective action or the standing of non-governmental organizations [40].

Inter alia, as a result of those developments, the possibilities to use liability rules have increased in the past decades. That has led to an important paradigm shift, whereby the notion that "the loss lies where it falls", indicating that victims must merely accept the unfortunate consequences of a disaster, is no longer accepted [41]. Additionally, due to the extensive coverage of disasters by mass media, they attract significant attention from politicians, leading to a requisite necessity for a certain type of disaster recovery. The question that arises is whether government intervention in disaster recovery, such as offering comprehensive compensation to those affected, is consistently economically efficient and legally just.

5. A Blended Role for Government Intervention in Disaster Governance

In this section, we ask the question of how far governments can and should be involved in compensating victims of disasters and how this would affect the prevention and resilience of disaster recovery.

5.1. Reasons and Types of Government Intervention

The question of why a government should contemplate compensating victims serves as a prerequisite inquiry before delving into the type of governmental intervention that merits consideration. First, there is a widespread argument that offering disaster compensation is one of the core responsibilities of the government [42]. Disasters frequently result in the complete upheaval of society. For instance, following a major nuclear explosion or a catastrophic earthquake, large parts of a municipality may become uninhabitable. Countless individuals are left homeless, and financial institutions may hold mortgages with little to no value. The potential ramifications for society as a whole, encompassing the economy and financial system, can be substantial and significant. Government compensation serves a crucial role in restoring victims to a semblance of normality [42].

In addition, government compensation for victims constitutes the delivery of public goods during disasters. Disasters differ from accidents suffered by individual victims in scale and scope. Addressing catastrophic damages and losses represents a typical public good that is inadequately addressed by private entities. Unlike private parties, the government possesses the ability to mobilize capital swiftly following catastrophes. This is facilitated through mechanisms such as issuing debt or government bonds, taxation (which serves as a form of risk diversification across the entire population), and spreading risks across future generations (a form of intertemporal risk diversification) [43]. Third, failing to provide relief and compensation to victims contradicts principles of solidarity, particularly in the social welfare systems within the member states of the European Union (EU) [44]. Conversely, providing compensation to thousands of victims can help to restore public trust in the government [45].

Government intervention in the areas of disasters often uses different interrelated instruments. For example, in the realm of nuclear liability, as a result of lobbying by the nuclear industry, the government imposes low limits on the liability (so-called financial caps) of the nuclear operator. It obviously impacts the liability rules, as we discussed above, and limits the compensation to the potential victims as well as the incentives for prevention of nuclear operators. So, in this type, there is a large amount of government intervention. The government does not directly intervene in the market. In this model, the role of the government primarily involves implementing administrative measures, such as establishing regulations for construction and land use, and safeguarding the functionality of a private market [46]. The second type involves government emergency relief, encompassing medical assistance, food aid, shelter, and direct financial support for victims during and after a disaster. Once a state of emergency is declared, the role that the government can play in various emergencies (both human-made and natural) is justified by its public good nature to correct market failure, as the incentives and resources necessary to embark on such initiatives are scarcely present in most private organizations [47].

When the state of emergency is over, ad hoc charity by the government and a structural fund for catastrophe victims are the third and fourth types, respectively. Both types aim to compensate for personal and property damages suffered by victims and restore conditions to what they were before the disaster occurred. These government interventions do not necessitate any action on the part of potential victims but involve direct payments to victims following a catastrophic event. The main distinction between the two lies in how compensation choices are rendered: either on an individual, specific instance depending on the damages incurred by each disaster, or through a structural solution through a compensation fund [48].

5.2. Pros and Cons of Government Intervention

Having provided an overview of different ways for the government to intervene in disaster recovery, this section will answer the question of which of these types can be seen as being the most economically efficient. The substantial losses and damages resulting from disasters, can lead to significant political and economic instability, and warrant government intervention. Consequently, there remains ongoing debate regarding the types of government compensation available to disaster victims.

Economic efficiency will serve as a yardstick for assessing the cost effectiveness of preventive action and the ability of ex post compensation mechanisms to stimulate those cost-effective preventive measures [9]. Such a yardstick can also have positive effects on the resilience of society as a whole with regard to disasters because such intervention would, on the one hand, have a preventive effect and, on the other hand, also enable the restoration of society if a disaster materializes. Government intervention takes various forms across different stages of disaster response. In this contribution, we focus on strengthening resilience for disaster recovery. However, it may be clear that the government obviously also has a pivotal position with regard to the prevention of disasters, more particularly, to protect critical infrastructure. Given the public good nature of those measures aiming at disaster risk reduction, these preventive measures (such as e.g., building dikes) will often be implemented by the government. However, this paper primarily delves into the realm of compensations and liability, leaving the physical measures of government intervention as an area for future exploration and elaboration. We aim to distinguish between emergency relief efforts and ex post direct compensation efforts, and measure whether they facilitate and strengthen economic efficiency.

5.2.1. Pros: Emergency Relief

Government emergency relief has traditionally garnered less focus compared to ex post direct compensation, and this is often contrasted with ex ante mechanisms such as insurance in the law and economics literature [49,50]. Emergency relief resembles the pivotal "golden hour" in emergency medical care, and the initial 72 h period after a disaster is of utmost significance. These initial 72 h are crucial, as the likelihood of finding survivors significantly diminishes beyond this timeframe, particularly in the aftermath of events like earthquakes. Hence, there are compelling reasons for the government to promptly deliver emergency relief.

Firstly, government emergency relief exhibits characteristics of a public good, as thousands of victims require swift assistance following unforeseen disasters. Due to the vast scale and unexpected nature of relief efforts, private entities might be constrained by both motivation and resources to implement emergency measures. Therefore, the government, via the orchestration of nationally coordinated initiatives and the consolidation of significant resources, is often best positioned to provide such assistance [51]. Secondly, emergency relief holds the potential to limit damages and yields positive ex post effects. It mitigates immediate damages that would otherwise need to be covered either by the affected individuals themselves or through concerted governmental rehabilitation initiatives. Given the news-sensitive nature of disasters, governments often lean towards oversupplying recovery efforts. Emergency relief can thus reduce overall recovery costs while also partially mitigating the weakening of incentives for proactive prevention, as fewer resources are diverted to ex post direct compensation [52].

5.2.2. Cons: Ex Post Direct Compensation

While governments in various jurisdictions often provide generous ex post compensation due to political considerations, criticism of this approach to government direct compensation is widely debated.

First and foremost, ex post government direct compensation as a single, upfront payment in its entirety provides negative incentives for prevention. As a result, the victim may not adopt a resilient attitude toward disasters, leading to a less secure environment

and higher death tolls [53]. The current challenge persists in being described as the "charity hazard", and this dilemma arises from the possibility that increased government recovery efforts may actually contribute to higher disaster losses, as individuals become less inclined to take precautionary and preventative measures [54]. Consequently, vulnerable victims lacking experience in disaster preparedness are more reliant on ex post assistance, further amplifying the impact of the disaster. In addition, if the government compensates victims of technological disasters, it would also favor potential injurers, since they are relieved of the compensation charge because the risk they generate will be compensated by the government. This exoneration gives such government intervention a subsidizing character, which can decrease the care incentives of potential injurers and, thus, reduce overall resilience. This argument is associated with the nuclear sector in France where, in the event of an accident, compensation is predominantly provided by the state [55]. One needs, however, to realize that the charity hazard due to underinsurance and government compensation only plays a role in those countries where insurance is available and victims have realistic alternatives (for example, relocating to safer areas). The charity hazard does often not arise in developing countries for the simple reason that either alternatives (like relocation to a safer area) are not available (for example, in a country like Bangladesh) or insurance is not available either. That is obviously a major problem in a large part of the developing world [56].

Second, ex post government direct compensation causes a political inefficiency problem since the reward received by politicians if they provide ex post compensation is much higher than if they invested in ex ante precautions. This leads, on the one hand, to neglected ex ante strategies, but, on the other hand, also to an oversupply of ex post compensation [10]. Politically driven compensation overly prioritizes issues sensitive to public perception, diverting resources from humanitarian compensation. For example, empirical studies indicate a correlation between election cycles and the extent of ex post government payments: "disasters occurring in election years attract more ex post funding relative to disasters in other years" [57]. This clearly contradicts the principle of equality, as victims of disasters that occur in election years receive more favorable treatment than those affected in other years [58]. This is also confirmed by the theory of public choice, which argues that governments are prone to intervene more frequently when the number of affected individuals reaches a critical threshold [59]. By doing so, governments attempt to sway potential voters in order to acquire or retain power, which exhibits possibly political interests behind the argument of victims' protection. There are many indications that disaster spending is largely driven by political motives, rather than geared towards the most pressing areas. For example, emergency response expenditures handled by the US Federal Emergency Management Agency (FEMA) is heavily influenced by political considerations: States that hold political significance for the president are more likely to receive disaster declarations, and financial allocations are higher in states with congressional delegates serving on FEMA's oversight committees [60].

Third, an ex post government direct compensation scheme may encounter financial waste and inefficiencies. If it becomes progressively inadequate for the expanding needs, and it may not be effectively designed to address them, given the strain regarding assistance budgets and lags in the disbursement process. Government funding typically occurs on an annual basis, leading to a widening gap between needs and available financing. Empirical study has also revealed that government aid allocations do not consistently align with the needs of victims [61,62]. Meanwhile, the theory of public choice underscores the economic burden associated with government intervention given the bureaucracy which, for example, may hinder the organizing of the financing of state compensation [63]. Government compensation programs may incur high administrative costs, encompassing salaries and wages for program administrators, claim processors, and auditors; expenses associated with developing claims and other application forms; and fees for communication with the public [64].

5.3. A Short Summary

We have already discussed that providing emergency relief can be justified and beneficial for the whole society. However, the government often finds it challenging to resist the temptation to offer generous amounts of direct compensation, whether through ad hoc or structural means, following disasters, despite the numerous arguments against it. This has been repeated by many governments [59]. In many countries, among the factors being evaluated is the question of whether the government can assume a role that is less disruptive yet provides stronger incentives for proactive prevention measures. Therefore, smart mixes that combine legal, policy, and market instruments make sense. This has led to an ongoing discussion about the role of ex ante instruments in the smart mixes, more particularly, insurance, for the compensation of victims and governance of disaster risks.

6. The Promises and Challenges of Insurance for Resilient Post-Disaster Recovery

Recognizing the fact that insurers can require risk-mitigation efforts to maintain cover so that they become an extension of reliance-based preventive policies of the government [65], this section explores how far insurance can and should play a role in compensating victims and stimulating preventive measures related to disasters and how this would affect the development of resilience against disasters. We should keep in mind that a well-functioning (re)insurance market is a pre-requisite for insurance to be applied as an instrument to increase resilience and to work as a means of prevention.

6.1. Ex Post Financial Mechanism of Insurance as Compensation

Insurance has been regarded as one of the most important instruments to cover disasters because of the expertise of insurers in risk management. Its risk management framework comprises evaluating potential hazards during the underwriting phase, mitigating risks via service and oversight of claims, and financing risk mitigation through pooling mechanisms [66]. Pooling allows insurance to contribute to compensating disaster victims for contingencies insured against, thus leveraging the law of large numbers [42].

From the perspective of the policyholder, the foundation of disaster insurance lies in their aversion to risk. Confronted with the unpredictability of future disasters, individuals are typically assumed to be risk averse "if she considers the utility of a certain prospect of money income to be higher than the expected utility of an uncertain prospect of equal expected monetary value" [67]. An individual who avoids risk tends to safeguard against potential financial losses by contributing a premium (a minimal upfront fee) to a collective, thereby lessening the impact of unforeseen expenses in the future. Insurers are ideally suited to assume the transferred risk because aggregating a considerable quantity of similar exposures into a collective enables statistically predictable outcomes [68].

In the realm of law and economics theory, compared to government-provided compensation programs, insurance is often commended as a private market solution which has advantages in lower transactions costs and higher efficiency in covering disasters [69,70]. Theoretically speaking, the insurance mechanism is deemed efficient as it adheres to the principle of "Pareto Efficiency" [71], wherein no one incurs damage, and an individual enhances their expected utility by transferring risk. Nonetheless, there is a remarkable exception in Switzerland where government housing insurance has lower costs than the private insurance scheme [46]. This is largely due to the fact that the government in Switzerland also uses its regulatory powers to enforce investments in disaster prevention.

Uncertainty is a relevant concept to risk, but it should be properly distinguished from other risks in the fundamental mechanism of insurance. Risk refers to a measurable exposure, while uncertainty pertains to an unmeasurable exposure [72]. The uncertainty of an exposure cannot be quantified or assigned a numerical value. This distinction is crucial for insuring disasters, as excessive unpredictability leads to uncertainty that makes it impossible to quantify the exposure to loss.

6.2. Ex Ante Precautionary Efforts of Insurance as Governance

Insurance has the potential to play a critical role in safeguarding populations and properties by offering incentives to implement efficient preventive measures. This ability of insurance to impose cost-effective risk mitigation measures has been coined as "insurance as governance" in managing catastrophe risk [73]. The notion of insurance as governance posits that insurance companies, aiming to reduce financial risks, will strive to shape policyholder behavior through the application of private regulatory approaches, primarily via underwriting practices and contractual loss mitigation strategies. In this context, insurance serves as a method to "outsource" government regulation by assuming behavior control functions over policyholders [65].

Some critics may oppose the concept of insurance as governance due to the issue of moral hazard. Moral hazard describes the tendency of insured individuals in vulnerable areas to be less cautious in avoiding losses than they would be without insurance coverage [74]. If left unchecked, moral hazard could have adverse societal effects; for instance, liability insurance for major greenhouse gas emitters might diminish the incentives for these emitters (potential tortfeasors for climate disaster victims) to invest in prevention measures [75]. However, insurers can fortunately mitigate the risk of moral hazard by using regulatory techniques and vigilant monitoring of policyholders' actions. This enables insurers to encourage cost-effective behaviors among policyholders, thereby enhancing overall resilience.

First, risk-based pricing gives policyholders the financial incentives to mitigate the risk of moral hazard and implement preventative strategies. Indeed, as the insurance premium is calculated based on anticipated total losses—found by multiplying the probability and severity of loss—mitigating either factor can potentially lower the premium. If the cost of implementing these measures is less than the premium discount, policyholders are inclined to undertake mitigation efforts to reduce the likelihood and/or severity of loss [76].

Second, insurers utilize various regulatory techniques throughout the underwriting and claims process. These techniques encompass deductibles, copayments, contract design, loss mitigation services, educational outreach to insureds, claims administration, and refusal to underwrite, among other measures [65,77]. In many cases, these services offered by insurers could make an important contribution, importantly, to mitigating disasters. For example, empirical study has found that insurance provides positive effects on pollution emissions, green innovation, and environmental loss compensation [78]. Furthermore, insurers fulfill the role of "knowledge leadership" by offering educational outreach to policyholders. For instance, the Turkish Catastrophe Insurance Pool (TCIP), which is "considered as a good example of catastrophe risk insurance for developing and middle-income countries", places significant emphasis on education to enhance public awareness of catastrophe risk [79]. TCIP strives to incorporate the principles of earthquake risk mitigation and insurance into educational curricula and textbooks.

6.3. The Disaster Insurance for Post-Disaster Recovery: Market Development and Potential Challenges

6.3.1. Insurance Products for Disasters

In theory, insurance presents an alluring framework for addressing disasters. Meanwhile, insurance companies are deeply engaged in addressing disasters in practice. It is widely recognized and included, for example, in the EU and beyond, that insurance enables the improvement of society's resilience against natural disasters [80].

Insurance companies underwrite different types of policies to cover disasters. The most widely used insurance policy for disasters is the so-called catastrophe insurance, which primarily covers catastrophic property losses, including losses incurred to homes, industrial facilities, and business interruption, caused by disasters [81]. For example, insurers paid USD 15.5 billion claims due to the havoc caused by the Hurricane Andrew in 1992, USD 48 billion in 2005 due to Hurricane Katrina, and USD 17.6 billion in 2008 due to Hurricane Ike in the United States [82].

The second type is liability insurance. Many corporations, including power plants and auto manufacturers, face lawsuits related to commercial general liability, product liability, environmental liability, and professional liability stemming from both technological and natural disasters. For example, Commercial General Liability (CGL) insurance may provide such coverage to help the insured bear such liabilities even those caused by climate change. In the case of AES v. Steadfast, the decision of the Virginia Supreme Court directly implicated climate change claims in a liability policy [83]. Such liability might trigger insurers' duties of defense and indemnity to policyholders, not to mention technological disasters, where a liable tortfeasor can be identified and the damage can be directly attributed.

The third type is the insurance-linked securities, which are new products that provide capital and help to address losses and damages caused by catastrophes [84]. They enable insurers to transfer disaster risks to the capital market and provide insurers with additional capacity for coverage [85]. Take, for example, catastrophe bonds which are the most prominent and popular form of insurance-linked securities now [86]. The first catastrophe bond issued in 1997 by the United Services Automobile Association (an insurer) was a hurricane bond. It was crafted to augment the insurance sector's capabilities in response to the disproportionate USD 620 million loss incurred during Hurricane Andrew [87]. Despite the enormity of losses from disasters relative to the insurance industry's capacity, they represent a small percentage of the capital markets [88]. Through providing capital to cover catastrophic losses even in the case in which these high losses are expected, insurance-linked securities and other similar products facilitate resilient responses to disasters.

As well as underwriters compensating victims of disasters, insurers also contribute to pay the costs in providing active preventative measures like building dikes for floods and building resilient houses in communities [84]. As the primary investors in government bonds, stocks, and real estate, generally, insurers have the capacity to enable the building of resilient communities and to develop new preventative technologies [89].

6.3.2. Demand and Supply Challenges

Notwithstanding the theoretical advantages and many products of disaster insurance, the behavioral law and economic literatures indicate that people often fail to leverage these strengths to their utmost potential, leading to notable instances of underinsurance. Empirical data also indicate that disaster insurance schemes typically achieve low market penetration across legal frameworks devoid of compulsory provisions [14]. In the aftermath of recent natural disasters, such as flooding, in Europe and the United States, only a comparably minor proportion of victims were safeguarded by insurance policies, in addition to those in developing countries.

The subdued demand for disaster insurance is attributable to a variety of factors. Firstly, behavioral economics attributes consumers' anomalies to intuitive thinking biases and myopic loss aversion [90,91]. Cognitive limitations lead to systematic misjudgments of low-probability events like natural disasters, fostering an "it will not happen to me" attitude [92]. Secondly, data indicate that, prior to an event, individuals tend to favor uncertain losses over the guaranteed cost associated with paying an insurance premium. Insurance faces the certain loss of a premium, yet when it comes to disaster insurance, potential victims face the certainty of a premium payment with low expectations of returns over their lifetime, thus reducing demand [93]. Thirdly, ex post government compensation may also diminish incentives for purchasing insurance coverage.

Another barrier relates to the supplier's perspective, especially the "difficult to predict" nature of disasters. The primary concern is the likelihood of substantial losses arising from the occurrence of disasters, since they always cause highly correlated and aggregated damages. Many have argued that the catastrophic losses may potentially jeopardize the financial stability of insurance companies [94]. The limited capacity of individual insurers may prove insufficient to cover the extensive losses resulting from a catastrophe. Moreover, the high-stakes, low-probability nature of catastrophic events presents challenges for insur-

ance coverage. Despite the potential for underwriting disaster risks to maximize insurers' long-term expected profits, directors may hesitate to underwrite such policies. Additionally, their focus on short-term profitability, influenced by the separation of ownership and management control, could further exacerbate this reluctance [95].

6.4. A Short Summary: Insurance and Resilient Risk Society

Insurance is often championed as a resilient strategy for disaster mitigation within the well-known risk society. For instance, O'Hare et al. contend that "insurance represents an outsourcing of resilience to the private sector, where risk management is privatized and commodified" [96]. Collier et al. illustrate that insurance coverage for perils like floods, fires, and terrorist attacks plays a role in bolstering societal resilience [97].

The dual roles of insurance, encompassing compensation and governance in addressing the aforementioned disasters, indicates its potential to bolster risk mitigation and self-protection functions, thereby serving as a tool for bolstering resilience. Through mechanisms like risk-based pricing and regulatory strategies, insurance can foster a shared interest in guiding and allocating investments toward resilient initiatives. These endeavors, coupled with risk transfer, are poised to represent the most substantial contributions towards enhancing societal resilience.

7. Smart Mixes of Instruments to Promote Resilience and Sustainability for Disaster Recovery

7.1. The Need for Smart Mixes: Theoretical Foundations

As discussed above, three major types of instruments could be used to promote the resilience of disaster recovery. These instruments vary in terms of timing (pre- or post-disaster), form (monetary compensation or non-monetary preventive measures), and enforcement (public or private). However, each of these approaches is vulnerable to issues such as imperfect information, conflicting private interests, measurement inaccuracies, and inefficacy. The shortcomings of individual instruments highlight the necessity of developing a smart mix of tools to enhance both disaster mitigation and victims' compensation.

7.1.1. Market Failure

While insurance presents an appealing solution for managing disaster risk, offering lower transaction costs and higher efficiency compared to government intervention, it remains vulnerable to market failure. This susceptibility stems from barriers on both the supply and demand sides, as we discussed above. In addition, we explore two additional performances of market failure.

In the first place, disaster insurance markets have to be created deliberately or spontaneously by governments, firms, or individuals, particularly in developing countries where market failures are more common [98]. Take the catastrophe insurance market in China for example. Following the 2008 Great Sichuan Earthquake, the insurance market for catastrophes has still not fully developed, nor has it been officially established. If the laissez-faire theory were adhered to, the catastrophe insurance market in China is unlikely to progress swiftly and realize its potential in alleviating and funding losses resulting from catastrophic disasters [99]. As Karl Polanyi famously quipped, "laissez-faire was planned [100]". The government has recently taken action, initiating pilot initiatives for disaster insurance in the cities of Shenzhen and Ningbo, commencing in 2014.

Furthermore, liability rules, such as one market-based instrument discussed above, are likely have limited applicability to disaster recovery, resulting in what is termed as "liability failure". Firstly, the liability system imposes administrative costs on litigants, potentially leading to a caseload that falls below the desirable level when victims fail to consider the positive social externalities resulting from litigation for compensating disaster losses or deterring potential injurers [101]. Secondly, proving causation can be challenging, particularly in cases of complicated technological disasters with long-tail damage. In such instances, holding parties liable without clear causation could either lead to excessive

caution or market exit [101]. Thirdly, being ex post in nature, liability may not effectively address disaster risks or uncertainty. Fourthly, even if disaster harm can be successfully detected and proven, the available remedies may fall short of fully covering the actual losses incurred, (resulting in inadequate compensation) when a liable party is judgment-proof or unable to pay damages. Liability insurance may alleviate the under-compensation issue of liability rules. However, if moral hazard remains uncontrolled, liability may fail to provide ex ante deterrence to potential wrongdoers of disasters [101].

7.1.2. Government Failure

Promoting resilient disaster recovery relies on governmental intervention, but the government also faces overreaction or inaction [102]. Indeed, just as even the most robust market systems face "market failures", government interventions encounter numerous obstacles and challenges, often referred to as "government failures" [103]. As discussed earlier, although government intervention can be effective in providing immediate emergency relief in the short-term, its sustainability may be questionable for long-term direct compensation due to various reasons, as outlined in the drawbacks to ex post direct compensation.

Moreover, governments may not always react promptly to disaster challenges, which could stem from regulatory rigidity or the inherent uncertainty of disasters. Additionally, governments may lack sufficient information to determine the ideal level of intervention. The response of the U.S. federal government to Hurricane Katrina serves as a stark illustration of mismanagement and inadequate preparation in emergency relief and subsequent compensation efforts [104]. Lastly, disaster recovery is a matter of public concern, and it may be unrealistic to assume that governments consistently prioritize the public interest. For politicians, however, "the public interest is mixed with, and is often at odds with, their private and special interest [105]".

7.2. The Need for Smart Mixes: Practical Case Studies

7.2.1. China: The Whole-Nation System Embracing Insurance

Traditionally, the government has undertaken a significant responsibility in providing financial assistance to the victims of disasters in China. The Chinese distinctive history and political–economic configuration for containing natural disasters, known as the "Whole-Nation System", encompasses the government's strategy to mobilize and distribute resources across the entire nation to address emergency-driven disaster relief efforts [106]. Under the Whole-Nation System, the government coordinates national resources to tackle disasters, provide relief to victims, and spearhead reconstruction efforts in the best interest of the country. Fiscal support from the government serves as a significant capital source within this framework. It consists of three different types of responses: emergency response, direct payments to victims, and support in reconstruction [107,108].

While effective in delivering short-term governmental relief, the Whole-Nation System faces challenges in long-term sustainability due to inherent government failures, including the Samaritan's Dilemma, which means too generous compensation (government transfer) may dilute incentives for prevention [109]. This could diminish incentives for individuals to allocate funds towards preventative and alleviation strategies, resulting in fiscal pressures on public budgets and potentially hindering economic growth. Additionally, there may be shortcomings in risk financing mechanisms and incentives, which may foster rent-seeking behaviors and corruption. The aftermath of the 2008 Sichuan earthquake served as a stark reminder to policymakers of the imperative to enhance the Whole-Nation System. This includes the implementation of market-based pre-disaster preventive measures and post-disaster compensation measures. The fact that a mere 0.3 percent of total losses was covered by insurance underscores the necessity for such improvements [110]. Note, however, that the poor construction in the area (related to large losses) was not related to the Samaritan's Dilemma but to a poor province overseeing inadequate construction methods [111].

In 2014, the first experiment with a Disaster Insurance Pilot was launched in Shenzhen City [111]. This disaster insurance framework includes three different interacting layers.

The first layer encompasses the government-sponsored catastrophe insurance program, which is arranged by the Shenzhen municipal government through the Shenzhen branch of the People's Insurance Company of China (PICC). This insurance aims to provide basic assistance to all residents. The second layer involves a catastrophe fund, also administered by the Shenzhen city government. Capital sources of the catastrophe fund include government appropriations, social donations, and investment earnings. The third and final layer involves private catastrophe insurance, which is intended to cover property losses, in contrast to the first and second tiers of the Shenzhen insurance framework, which constitute government-funded policy coverage. Since then, more and more catastrophe insurance programs promoted by the government are established in different regions of China.

7.2.2. UK: Reform of Flood Private Insurance

Compared to the government's Whole-Nation System in China, the private flood insurance scheme in the UK, launched approximately five decades ago, serves as a case study demonstrating how mainly private market mechanisms can function [112]. Although the British government has established standards and regulations pertaining to flood protection, land use, and flood warning, it upholds the independence of privately administered compensation "arrangements" via a gentleman's agreement that clearly outlines the respective responsibilities of the state and the industry. Under this arrangement, private insurance companies provide compensation to victims in cases of flood damage. The old English flood insurance program existed before the introduction of the new Flood Re program and was considered efficient and sustainable. The challenge, however, lays in maintaining the accessibility and affordability of the old English flood insurance program, particularly to ensure that households in high-flood-risk areas could obtain it at reasonable rates amidst rising climate disasters [112].

The new Flood Re program was established through a gentleman's agreement between insurance companies and the government. In this agreement, the government pledged to undertake substantial investments in preventative measures aimed at reducing flood risks, and insurers, in return, offered insurance coverage accordingly [113]. The Flood Re model draws inspiration from Pool Re, a reinsurance framework established in 1993 in response to the looming threat posed by the Irish Republican Army and other terrorist activities, specifically designed to mitigate terrorism-related risks. However, in recent years, the Flood Re program has encountered difficulties, as insurers contend that the government has fallen short in fulfilling its commitments, particularly in terms of inadequate investments in flood prevention measures. To address this, the UK government has updated building regulations, now mandating that residents implement disaster resilience and resistance measures in their properties [114].

7.2.3. France: Caisse Centrale de Réassurance (CCR)

The French Caisse Centrale de Réassurance (CCR) model appears to strike a balance between the two approaches mentioned above. In this model, private insurers assume the underwriting of disaster risk, similar to other lines in the private market. However, the government serves as a backstop by providing additional capacity through reinsurance. Consequently, private insurers can leverage a state guarantee if the CCR's resources are depleted [115].

Pursuant to the Act of 13 July 1982 in France, all voluntary first-party insurance policies that cover property damage inherently include mandatory supplementary coverage for natural disasters. While there is no universal requirement to obtain insurance against natural disasters, this additional coverage is mandatory for those who voluntarily opt for property insurance contracts. In practice, everyone who cannot afford to buy a house with cash and thus needs a loan will need a mortgage. The bank will always require housing insurance as otherwise, the collateral, i.e., the home, can become worthless after flooding. Consequently, all those are automatically protected in the French model. The only ones excluded are those who can buy a house without a loan, but that is a very small group that

does not need protection anyway. Therefore, this French model does solve the demand challenges of the consumers who used to be unwilling to purchase low probability but high damage coverage due to cognitive bias.

Insurers are liable to compensate for damages only in cases where the government formally declares a specific event to be a natural disaster. Upon such a declaration, the affected individuals can submit claims to their insurers. According to the French Insurance Code, insurers are obligated to provide financial compensation within three months of receiving a victim's claim. A prime example of this French model in action is the management of the 2016 flooding of the Seine (and Loire) rivers, where over 182,000 claims were reported, resulting in insurers incurring costs exceeding EUR 1.4 billion [115].

French insurers obtain reinsurance through the Caisse Centrale des Réassurances (CCR), which is entirely state-controlled. Although engaging in reinsurance with the CCR is not a compulsory requirement, insurers retain the discretion to establish agreements with alternative private reinsurers. However, many opt for the CCR due to its relatively low premiums and the advantage of unlimited coverage backed by a state guarantee if the CCR's resources are depleted [46]. In such cases, the state assumes the role of a reinsurer for the CCR, with the CCR obligated to remit a premium payment to the state. This state intervention was evident in the 2016 floods, where the CCR intervened to cover EUR 623 million of the total EUR 1.4 billion costs [115].

The U.S. federal guaranteed terrorism insurance and the Turkish Catastrophe Insurance Pool follow a comparable operational framework. In the French CCR model, insurers handle primary coverage underwriting, while the government offers subsidized reinsurance with an unlimited guarantee and collaborates with private insurers to develop prevention and mitigation strategies. This arrangement allows primary insurers to offer disaster insurance policies to homeowners at affordable rates [46].

While more promising than previous models, this approach still has its drawbacks. Government-backed reinsurance schemes often incorporate subsidized rates, potentially eroding the motivation for mitigating disaster risks. Moreover, in contrast to private insurers who are compelled by market competition, governments might confront political pressures, resulting in less robust pricing mechanisms. This can lead to pricing that does not accurately mirror the true level of risk and thus may not offer adequate incentives for reducing disaster risks [116].

7.2.4. Germany: Failed to Follow French Model

Germany boasts a comprehensive collection of stringent liability laws, encompassed in regulatory frameworks such as the Environmental Liability Act and the Gene Technic Act [117]. These statutes impose strict liability for technological catastrophes, such as train derailments or tunnel fires [115]. However, they are often deemed inadequate in scope and typically do not cover natural disasters. In cases of widespread damage from such disasters, the government may step in with legislation to offer ex post ad hoc compensation [44]. However, empirical research indicated that the ad hoc ex post compensation led to a considerable market disruption in terms of a lackluster demand for insurance coverage in Germany [118].

Influenced by the criticism of the German system, several reforms have been proposed, with the most significant ones revolving around the adoption of mandatory comprehensive disaster insurance, similar to the above French model [44]. Political debates on this matter occurred in 2004, but they did not result in legislative action. "Ad hoc aid gives the decision makers greater discretion in their response to natural disasters than regulated benefits" [44]. The case of the Elbe flood in 2006 serves as an illustrative example of this issue: "Chancellor Schröder's energetic and sympathetic efforts to help Saxony during the floods led to the governing parties' renewed popularity, helping the social democrats to win the 2006 election" [44]. This case in Germany once again highlights the challenge of implementing mandatory insurance, as it competes with the political appeal of providing excessive (albeit inefficient) ex post ad hoc compensation [44,115].

7.2.5. Turkey: Turkish Compulsory Insurance Pool

In contrast to Germany, Turkey implemented Governmental Decree Law No. 587 on Compulsory Earthquake Insurance in 1999, establishing the Turkish Compulsory Insurance Pool (TCIP). Operating as a marketplace safeguard, the TCIP provides earthquake insurance to property owners, safeguarding against losses caused by earthquakes and affiliated disasters such as fires, explosions, landslides, and tsunamis. The framework for this mandatory earthquake insurance system is laid out in the Disaster Insurance Law (Law No. 6305), which aims to mitigate fraudulent claims and enhance participation levels [119].

The TCIP operates as a public entity, with the government appointing an insurance or reinsurance company to manage its day-to-day operations [120]. These companies handle all aspects of the TCIP's operations, including underwriting, claim management, and reinsurance, without assuming any risk themselves. Additionally, in cases where claim payments surpass the TCIP's capacity, the state offers contingent liquidity support [121].

In addition to compensating earthquake victims, the TCIP serves as a loss mitigation system. It has significantly contributed to the improvement and oversight of Turkey's National Building Code [118] and, subsequently, has implemented revisions in land-utilization strategies and additional risk reduction measures [14]. Furthermore, the TCIP places great emphasis on education aimed at increasing public awareness of catastrophe risk. For instance, it strives to incorporate the principles of earthquake risk mitigation and insurance into educational curricula [121].

7.3. Exploring Resilient and Sustainable Smart Mixes

Although there is a large variety of instruments available, including both market-based and command-and-control mechanisms, indeed, each instrument has its own set of advantages and weaknesses and is applied in selected states as discussed above (see Table 1). They could, however, equally be used in combination [122]. As evidenced by the case studies we have examined, it is clear that no single instrument can achieve effective results on its own. This suggests that, in many situations, a combination of different instruments is necessary for effective disaster risk management. This section searches for smart or effective mixes of instruments, and deals with the crucial question of how smart mixes of legal and policy tools can be designed to effectively improve the resilience of disaster recovery.

Table 1. Summary of Mechanisms and Exploring Smart Mixes for Post-Disaster Recovery in Selected States.

Approaches / States	Liability Rules	Government Intervention	Disaster Insurance	Exploring Smart Mixes of Instruments
China	In theory possible in all countries, but not applied to cover natural disasters	Yes. Whole-Nation System		"Government Failure" and Embracing Insurance
UK			Yes. Flood Private Insurance	"Market Failure" and a new Flood Re program through a gentleman's agreement between insurance companies and the government
France		Yes. Government-backed reinsurance	Yes. Primary coverage underwriting by insurers	Caisse Centrale de Réassurance (CCR): mandatory comprehensive disaster insurance program through Public-Private Partnership (PPP)
Germany			Yes. Private insurance without mandatory requirement	Failed to adopt CCR model program
Turkey		Yes	Yes	Turkish Compulsory Insurance Pool (TCIP) through Public-Private Partnership (PPP)

7.3.1. Command-and-Control System Versus Market-Based Instruments

Indeed, a comprehensive collection of literature has delved into the comparison of the traditional command-and-control approach, often led by government intervention, with more incentive-based mechanisms facilitated by market dynamics [123]. While research readily highlights the potential of incentive-based mechanisms to significantly reduce losses and foster the adoption of preventive measures over time, it is crucial to mention that market-based systems are not inherently superior to command-and-control approaches, especially when the latter are tailored to prioritize cost savings or prevention incentives. Care must be taken not to overly dichotomize these approaches, as command-and-control strategies encompass a diverse array of measures. Some of these measures may seem rudimentary, yet they can yield results as effective as economic incentives. Take, for instance, the emergency response coordinated by the government immediately following a disaster—a critical intervention applauded for its inherent public good nature, particularly since few private entities have the motivation to take such swift action [47,52]. Moreover, government relief efforts help address the affordability challenges faced by low-income individuals seeking remuneration solutions. It could "assist those who cannot afford to invest protective measures, ... against catastrophic losses for risks that are considered uninsurable by the private sector alone [124]".

Indeed, the distinction between command-and-control approaches and market-based mechanisms warrants caution. Attempting to compare or prioritize one over the other without considering the specific context, type of disasters, and institutional framework is imprudent. The efficacy of each approach varies greatly depending on these factors, making it impossible to make sweeping generalizations about the superiority of one over the other.

The experiences in the aforementioned countries highlight the importance of avoiding ex post government-funded compensation for recovery. Using taxpayers' money to finance recovery efforts can undermine incentives for prevention and mitigation by victims [117]. However, this principle of avoiding the use of public funds only applies to recovery efforts, not to emergency-driven disaster relief. As illustrated in the case of China, relief efforts immediately following a disaster do not have a detrimental effect on ex ante incentives for prevention. Moreover, governments have effectively created market solutions, as seen in France and Turkey, where victims can rely on insurance coverage for natural disasters' compensation due to mandatory insurance provisions [117]. More details will be discussed in the next section.

7.3.2. Mandatory (Liability) Insurance as a Favorable Patten of Instrument Mix: Insurance (and Liability) Meets Regulation

Introducing mandatory insurance is one form of government intervention to facilitate disaster insurance. Mandatory insurance has not been unequivocally accepted, especially when such a system would also oblige individuals who would not need such an insurance to purchase it. Nevertheless, there is support amongst law and economics scholars for such an intervention, provided it is possible to limit the duty to purchase catastrophe cover to those directly exposed to risk [45]. Compulsory insurance is also believed to have a significant impact on enhancing hazard perception and, broadly speaking, resilience [9], especially in the light of government's inability to refuse post-disaster compensation [125]. Moreover, mandatory insurance coupled with the government serving as the ultimate reinsurer has the advantage of circumventing the adverse impacts associated with providing compensation from public funds [117].

The necessity of purchasing insurance, whether mandated by law or practicality, plays a significant role in the private governance of insurance. Numerous investigations reveal that in workers' compensation insurance, which is typically mandated by law, the employment of technical tools can contribute to the minimization of losses and enhancement of safety [126,127]. Similarly, evidence suggests that risk-based pricing and deductibles, imposed by mandatory auto liability insurers, promote safer driving practices [128,129]. In-

surers functioning in lines of coverage that are essentially mandatory are highly motivated to observe a reduction in total risk, particularly in the shorter to mid-term horizons [130]. However, the insured who encounter substantial premium hikes stemming from prior losses find it challenging to terminate or scale down their insurance coverage [131]. Under mandated private insurance, those aiming to reduce their insurance premiums are inclined to implement preventative or risk mitigation measures. Consequently, the imposition of mandatory insurance can aid in bolstering efforts to mitigate damages. As Telesetsky contends, "the most important reason for mandating catastrophe risk insurance is to compel industry actors to take action under the supervision of the profit-motivated insurance industry [75]".

In the context of disasters, behavioral biases like bounded rationality often lead individuals to adopt an "it will not happen to me" mindset, resulting in a reluctance to purchase insurance coverage for low-probability, high-loss events, despite the potential utility it could provide [69,132]. Mandatory coverage offers a clear advantage in mitigating the issue of adverse selection by encompassing all potential risks, favorable and unfavorable, under its mandatory framework. Through customized pricing and segmented risk management, mandatory coverage also helps mitigate the moral hazard problem. Several countries, including France, Belgium, Norway, and Spain, have recognized the efficacy of such mandatory compensation systems for specific natural catastrophes, thereby ensuring broader risk coverage and addressing behavioral biases that may hinder individual risk management decisions [133,134]. The experience analyzed in France further illustrates that the country's insurance markets, coupled with state reinsurance, are effectively equipped to provide compensation without relying on public funds to assist victims of natural catastrophes [117]. In the event of technological disasters, mandatory liability insurance offers an ideal blend of liability, insurance, and governmental involvement. By imposing a regulatory obligation for industrial operators to secure financial guarantees, such as insurance, this approach addresses both the insolvency issue (commonly known as the judgment–proof problem) and the under-deterrence problem among wrongdoers [38].

7.3.3. Public–Private Partnership (PPP) as a Promising Mix Model

This section will explore how the public-private partnership as a feasible and smart mix model, could supply efficient prevention incentives, sufficient compensation for victims, and thus realize welfare maximization. Since there are different types of PPP but without a unified definition, we try to outline the guiding principles of PPP for fair and efficient disaster recovery in order to realize "the potential to transfer risk to the party most able to bear it–that is, the party that can best manage it or mitigate it" [135]. The concept of PPP to deal with resilient post-disaster recovery has also been promoted by the World Bank [136].

Embracing the Merits of Both Government and Market

The majority of criticism directed at government efforts, as examined above, pertains to ex post direct compensation rather than emergency relief. Without a doubt, a collaboration between public and private sectors in a PPP framework ought to prioritize immediate governmental aid, as it addresses the affordability issues which low-income residents encounter in seeking compensation, while also delivering crucial medical care, nourishment, shelter, and vital public services to victims in the wake of a disaster. Those services are often inadequately provided by private entities.

Meanwhile, it is unequivocally accepted that private insurance should follow the market approach, especially charging risk-related premiums for disasters [137]. Implementing risk-based premiums offers the advantage of signaling to individuals the risks they genuinely face. When premiums are determined based on risk, individuals are incentivized to invest more in preventive measures. Those investments can lead to lower premiums for the insured. Consequently, even a state-provided reinsurance program should reflect the actual risk. Without risk-based pricing, other participants in the reinsurance sector would be unable to compete with the government, leading to government intervention that distorts

the market and subsidizes certain players. In addition to risk-based pricing, insurers utilize various techniques, such as deductibles, exclusions, and loss-reduction services, to mitigate risk. Overall, insurers have the potential to function as private risk regulators.

Solving Both the Market Failure and Government Failure

To overcome the supply and demand barriers in the private insurance market and promote the role of insurance in disaster recovery, government intervention ought to facilitate and stimulate rather than distort the market. For instance, to tackle the supply constraints, the government could assume the role of a reinsurer, effectively bridging the "capacity gap" faced by primary insurers in covering disasters, thus augmenting their underwriting capabilities. To alleviate demand constraints, the government should minimize or altogether eliminate the need for post-disaster government recovery payments. Moreover, to address issues of lacking demand and adverse selection among potential victims, the government might implement mandatory rules, similarly to France's mandatory comprehensive disaster insurance model. According to Act No. 82-600 of 13 July 1982 on the Indemnification of Victims of Natural Catastrophes, for example, "property insurance policies that cover damage against property are automatically and mandatorily insured against the risk of natural disasters" [46]. Additionally, to facilitate insurance operations, the government should provide essential public infrastructure like levees and establish regulations and guidelines for disaster prevention and mitigation. Meanwhile, special attention should be given to low-income residents by offering means-tested vouchers covering parts of the insurance costs, as well as providing mitigation grants and loans to help them afford insurance while ensuring that premiums reflect risk [138]. Last but not the least, the government should allow individual insurers the freedom to choose whether to utilize state (re)insurance and charge risk-based premiums. This approach encourages insurers to seek cost-effective alternatives while maintaining market flexibility.

To address or prevent government failure, government interventions should typically be temporary in nature. By implementing "sunset provisions", the government can ensure that interventions do not unnecessarily disrupt competition in the private market over the long term [46]. This is, of course, true only if it is assumed that particular exceptional circumstances caused the inability of the ordinary (re)insurance market to insure certain risks, as was seen, for example, in the case of uncertainties that arose in the terrorism insurance market after 9/11.

This type of PPP is particularly attractive for developing countries as the greater granularity in insurance risk is leading to retail insurers leaving regions of high fire, flood, and storm risks, as a result of which insurance is (particularly in developing countries) often no longer available to cover catastrophic risks. And where insurance is available, premiums are often unaffordable. That is not an argument for direct government intervention, but rather for a PPP that can function as a disaster safety net in developing countries [38]. The government could equally subsidize the purchase of insurance through a voucher system whereby the subsidy would be provided only if particular preventive measures were implemented, thus contributing to risk awareness and prevention [135].

In case of technological disasters, there are more challenges both in government and market. Taking the nuclear accident for example, a lower cap on the liability of industrial operators is introduced following the implementation of international conventions, even though the average costs of such accidents are much higher, due to the lobbying for conventions by the relevant interest groups [38]. Government safety regulations often arise in response to market failures, especially shortcomings in liability rules. However, the influence of lobbying and rent-seeking practices can sometimes lead to the lowering of standards to such an extent that government intervention itself becomes problematic. This can result in a situation where the problem of under-deterrence persists, albeit in a different form. Therefore, a balanced approach to controlling technological disaster risks involves an integration of governmental safety oversight and liability rules. These mechanisms can establish effective safety standards that industries must adhere to. For instance, if

compliance with regulatory standards is seen merely as a minimum requirement rather than a defense, liability rules can incentivize industries to take additional precautions to reduce the expected costs of accidents. Moreover, the duty of insurance coverage should be capped at an insurable amount, with operators remaining liable for any costs beyond that limit.

7.3.4. Recommendations

From the above discussion, we could conclude that there exists an effective blend of liability rules, government intervention, and insurance, where they synergistically interact to serve the public interest and enhance the resilience of disaster recovery.

First, concerning liability rules, they should be introduced with human-made disasters tortfeasors ensuring adequate access to justice and information, and could provide prevention incentives. At the same time, to uphold the deterrent effect of liability rules, it is necessary to enforce compulsory solvency guarantees (such as insurance) up to insurable amounts, coupled with unfettered liability for any remaining amounts, thereby eliminating financial limitations.

Second, for insurance, in the context of natural catastrophes, a system of comprehensive mandatory insurance cover should be introduced to deal with demand-side problems. Except for some unique developed countries, like Sweden, where substantial coverage exists even without a legal requirement to purchase insurance for disasters. However, in countries where disaster coverage is not readily accessible, mandating the purchase of such coverage becomes necessary, ideally as an addition to existing voluntary insurance arrangements [117]. There have been several studies showing that in countries where there is no mandatory disaster insurance, coverage will be structurally too low, such as, for example, in Germany [139]. In countries where disaster cover has been made mandatory, the scope of coverage is obviously much wider, such as, for example, in France [44]. In addition, the mandatory supplementary disaster coverage should align closely with market principles. Through differentiated insurance policies, insurers would effectively manage moral hazard within industries, leveraging a combination of public and private regulation.

Third, for government, it is crucial to avoid providing ex post government-funded compensation for recovery. However, government intervention could act as a last resort for low-income residents to solve the affordability concerns and for private insurers to assume risk for any losses exceeding a predefined threshold. Furthermore, the government should encourage the establishment of comprehensive mandatory insurance for losses resulting from disasters, for example, through providing data and information.

Fourth, Public–Private Partnership, public enforcement agencies, private standard-setting bodies, and insurers would collaborate to enforce safety standards and implement disaster prevention measures. A smart mix should be developed for both ex ante and ex post mechanisms, whereby (1) a comprehensive mandatory insurance cover should be structured; (2) the government assumes the role of reinsurer as the last resort; and (3) "meta-planning", which would enable better performance in ex ante preventive measures and emergency situations arising from disruptive events through a systemic, structural solution rather than ad hoc ex post solution, should be adopted by public institutions and non-governmental stakeholders [15] in order to stimulate the willingness of policyholders and capacity of the insurance market, address the problems across both the supply and demand landscapes, and thus boost resilience and sustainability of post-disaster recovery.

The crucial point is that the legal and institutional context, as well as the type of disasters, the pre-existing environment, related government arrangements and existing levels of resilience are all important in defining which type of mix of mechanisms might be smart (in the sense of promoting resilient post-recovery) in a specific country. There is, in other words, not a "one-size-fits-all" smart mix as the ability of (a combination of) particular mechanisms to achieve resilient post-disaster recovery may depend on the specific legal and institutional contexts in which the particular mechanisms will have to function.

8. Conclusions

The data and forecasts are unequivocal: climate change, AI, and cyber-attacks will trigger an increase in both natural and human-made disasters and will result in more frequent natural and human-made disasters, leading to escalating damages. Disaster recovery involves various stakeholders, including individuals, governments, and professional associations. However, not all of these stakeholders are incentivized to prevent disasters, and they may fail to collaborate effectively. Theoretical analysis suggests that a variety of instruments, such as liability rules, government intervention, and insurance, can be employed to promote disaster recovery. So far, the literature roughly indicated a preference for one specific type of instruments, depending upon the nature of the disasters (mostly liability rules and liability insurance for man-made disasters) [37] and first-party insurance for natural disasters [69]. We argued that no single instrument in isolation can adequately address all the challenges faced in disaster recovery. For example, liability rules may be more applicable to technological disasters, but specific conditions must be met for a liability regime to function, including strict and unlimited liability. Injurers should be held accountable for the full cost of the damage they cause, incentivizing them to prevent disasters. Government intervention and insurance mechanism face government failure or market failure, respectively. Therefore, this article argues for the exploration of a smart mix of instruments to enhance the resilience of disaster recovery efforts. We therefore add to the existing literature by showing that, in most cases, there may not be one single instrument able to provide resilient post-disaster recovery, but rather that it is indicated to search for a smart mix of different types of instruments.

In many countries, there are currently reforms and discussions about the schemes for disaster recovery. Smart mixes of instruments are increasingly used. In those schemes, the government often takes a facilitative role to foster the effective operation and vitality of insurance markets. One may notice that, for example, the Caisse Centrale de Réassurance (CCR) model illustrates the successful joint use of instruments to enhance the resilience of disaster recovery. Similarly, other European Union member states are increasingly adopting similar public–private partnership (PPP) mechanisms, where private insurance coverage is supported by government-sponsored reinsurance. Although there is, in many jurisdictions, a strong development towards the practical application of PPP strategies for resilient disaster recovery [140,141], there are, as the case studies showed, still jurisdictions where PPPs have not been developed and there is a strong reliance on just one particular mechanism [142]. The reason why a smart PPP is not developed is often political [17]. Similarly, the use of compensation for disaster victims can often be politicized. Also, China still predominantly relies on government emergency relief but is gradually transitioning towards ex ante insurance to reduce ex-post government recovery. Our analysis and recommendations advocate for a smart mix of liability rules, government intervention, and insurance, where these elements interact to provide more effective compensation for disaster victims while simultaneously contributing to disaster risk reduction. This approach aims to promote resilience in disaster recovery efforts. Of course, still more research may be needed, for example, concerning the question of what would exactly constitute a "smart" mix of instruments in the particular legal–cultural context of specific jurisdictions. Indeed, given path dependency and the existing institutional and social structures, it is very well possible that there is not just one effective combination of instruments that would fit each jurisdiction. The smartness of such a combination may well depend upon the specific features of the country concerned and its particular institutional and legal–cultural context. Which mix of instruments can therefore be considered effective to reach a resilient post-disaster recovery in a particular jurisdiction is therefore undoubtedly an issue which merits further research.

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