Designing Public Reinsurance:

Global Lessons for the U.S.

Adam Solomon
NYU Stern

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Insurance markets globally are buckling under the pressure of increasingly severe natural catastrophes. Direct public provision of insurance—the traditional policy response—has often failed to address the underlying market frictions and in many cases has accentuated them. A novel and increasingly popular alternative is public reinsurance: government-backed protection for insurers against catastrophe tail risk, rather than direct coverage of households. I provide the first comprehensive survey of public reinsurance programs around the world, cataloguing their design along key dimensions including pricing, participation rules, mitigation incentives, risk coverage, payment triggers, and shortfall financing. Drawing on evidence from programs spanning flood, earthquake, hurricane, and multi-peril catastrophe risk across dozens of countries, I evaluate the advantages and disadvantages of each design choice. I conclude with lessons for the design of a potential U.S. public catastrophe reinsurer.

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1. Introduction

Insurance markets globally are buckling under the pressure of more frequent and more severe natural catastrophes. All over the world, homeowners and small businesses face large premium increases, coverage restrictions or outright unavailability. These patterns are global and therefore not primarily due to regulatory frictions in particular jurisdictions. Instead, they reflect fundamental market failures that arise when insuring natural catastrophes: moral hazard from underpriced insurance that distorts location and mitigation choices, charity hazard from ex-post aid, and, most importantly, frictions due to correlated risk.

For the last century, the common government response to insurance-market dysfunction has been direct public provision of insurance. The government acts as the primary insurer, charging premiums to households or firms and paying claims when disasters occur. These programs have clear strengths: they can catalyze markets where none exist and expand coverage in high-risk areas. However, common issues have arisen in many public insurance programs around the world. Premiums are often heavily subsidized or cross-subsidized, diluting risk signals and distorting incentives for mitigation or relocation. Political pressure makes subsidies difficult to remove. Public insurance can crowd out or prevent the emergence of private markets even when the latter might be viable, and large disasters can overwhelm the centralized public agencies that administer these programs.

These limitations, combined with the particular features of natural catastrophe risk have motivated a novel type of government intervention: public reinsurance. Reinsurance is insurance for insurers. Rather than directly insuring households, governments intervene to offer protection against tail shocks to insurers. Public reinsurance typically covers a defined slice of catastrophic risk, for example, hurricane or flood losses or officially declared disaster events, while leaving the pricing, underwriting, claims management and idiosyncratic risk to private insurers. The rationale is to leverage the size and diversification of the public balance sheet to add to the supply of capital available in private markets where it is most strained: correlated tail risks. Public reinsurance has become standard for terrorism since the 1990s, and analogous programs to cover natural catastrophe risk have emerged in many countries around the world, and are being actively discussed by academics[1] and politicians[2] in the US.

This paper has four goals. First, I discuss the primary market failures that affect

[1] [24]
[2] [95]

catastrophe-exposed insurance: moral hazard, externalities, imperfect competition and search frictions, and capital constraints that arise from concentrated losses. Second, I discuss why direct public provision of insurance has not managed to address these frictions and in many cases has accentuated them. Third, I provide a comprehensive overview of public reinsurance programs from around the world. I categorize each according to the key design dimensions along which there is substantial variation: (i) who is reinsured; (ii) how the program is priced; (iii) how mitigation incentives are incorporated; (iv) whether participation by insurers is mandatory or voluntary, (v) which risks are covered; and (vi) how any shortfalls between claims and premiums are financed. Fourth, I discuss advantages and disadvantages of each of these dimensions, and use the best available empirical evidence to evaluate the extent to which these design choices have fulfilled or not fulfilled their goals, and where evidence is thin or absent.

The remainder of the paper is organized as follows. Section 2 reviews the key market failures in catastrophe-exposed insurance and reinsurance markets and examines the implications for public intervention. Section 3 summarizes the mixed experience with direct public insurance provision. Section 4 then gives a comprehensive catalog of extant public reinsurance programs and categorizes them along the core design dimensions above. Sections 5 through 10 discuss, in turn, the primary advantages and disadvantages of each of the relevant design choices and summarize the extent to which there is empirical evidence supporting each. In light of the evidence, Section 11 discusses the implications for a potential U.S. public natural-catastrophe reinsurer. Section 12 concludes.

2. Market Failures in Catastrophe Insurance

Catastrophe-exposed insurance markets are affected by several market failures. I focus here on those I judge to be most important for the design of public reinsurance.

2.1. Moral Hazard and Loss Reduction

A central friction in insurance markets is moral hazard: once insured, individuals may exert less effort to prevent or reduce losses. In standard models, coverage weakens incentives to take costly preventive actions (ex ante moral hazard) or encourages more intensive claiming and repair (ex post moral hazard). The theory[3] is by now well understood, and a large empirical literature documents behavioral responses to coverage and cost-sharing

[3] See, for example, [2], [100], and the discussion in [33].

in settings such as health, auto, and workers' compensation insurance.[4]

In natural catastrophe insurance, moral hazard manifests primarily through households' and communities' choices over mitigation and exposure—whether to elevate a home, install hurricane shutters, harden structures against wildfire, or build in particularly exposed locations. Recent work in disaster insurance settings suggests that insurance coverage and expectations of ex post aid can indeed dampen incentives for mitigation, although the magnitude varies by context.[5] As a result, standard instruments such as deductibles and premium credits for mitigation are often complemented by building codes, land-use regulation, targeted mitigation subsidies or loans, and the conditioning of post-disaster aid on observable mitigation and insurance coverage. This is one of the most important frictions that the design of public reinsurance must account for.

2.2. Charity Hazard and the Samaritan's Dilemma

Closely related to moral hazard, commitments of ex-post assistance from public or private sources create a "Samaritan's dilemma". When aid is promised by governments and the uninsured cannot be excluded, households rationally reduce their insurance purchases, instead relying on transfers after the fact. In the original models, unconditional aid generates a market failure of underinsurance that can be fixed by insurance subsidies.[6]

Natural catastrophe insurance is acutely exposed to the Samaritan's dilemma. Disasters are large and highly salient, generating enormous political pressure for ex-post aid. Much disaster aid is minimally conditioned on prior insurance, as the exclusion of households from disaster aid is seen to be morally and politically unconscionable. A growing body of evidence confirms[7] that ex-post aid crowds out ex-ante insurance coverage. The disaster aid that households rely upon is often incomplete, delayed and misunderstood. This provides a strong justification for public intervention in insurance or reinsurance markets. A budget-neutral or explicitly subsidized intervention that raised ex-ante insurance coverage could account for and correct the reliance on ex-post aid.

[4] For instance, the RAND Health Insurance Experiment and subsequent work show that higher cost sharing reduces medical utilization and spending; see, e.g., [75] and the summary in [33]. Similar patterns appear for accident frequency and reporting in auto and workplace insurance.

[5] For example, [60] investigate moral hazard in flood insurance markets in Germany and the United States, finding limited evidence of its presence, and [52] quantify how both subsidized premiums and anticipated disaster assistance can reduce private incentives to adapt to flood risk.

[6] See, for example, the original formulation in Buchanan [16] and the formal treatment in Coate [23].

[7] See, for example, [72], [29], [32] and [103].

2.3. Externalities

Frictions arise when individual insurance and mitigation decisions generate spillovers onto others. In settings of accidental loss, such as auto insurance, liability insurance, the standard remedy is through mandatory third party insurance and the tort system. In natural catastrophe insurance, externalities are multiple. Elevating or hardening a structure can change flood paths ([122]), and increasing 'defensible space' between nearby vegetation and a structure can reduce fire risk for that structure and for all nearby ([8, 114]). Post-disaster rebuilding decisions spill over to housing prices, local economic activity and tax bases (Fu and Gregory [46]). Insurance or reinsurance against natural catastrophe risk concerns itself only with the expected losses of the insured structure; spillovers and externalities are explicitly ignored. Regulations such as building codes, land-use regulation, mitigation subsidies and public investment can go some way to internalizing these spillovers ([59]). Well-designed public insurance or reinsurance programs could set premium incentives for risk reduction that incorporate both own and spillover effects.

2.4. Imperfect Competition and Search Frictions

Imperfect competition is a standard rationale for public intervention. Insurance markets depart from the competitive benchmark in important ways, two of which are most relevant here: high search costs combined with differentiated products, and the need for scale to achieve diversification. Products offered by different insurers have many different exclusions, limits and policy parameters that make a direct comparison difficult ([3]). Moreover, to obtain a quote a long insurer-specific series of questions needs to be filled out; direct comparison sites are rare ([4]). This allows a market with many players to maintain high markups and super-normal profits.

These concerns are likely amplified in catastrophe-exposed home insurance. To sell such insurance, insurers or reinsurers require large, diversified portfolios and sophisticated modeling technology. These returns to scale and fixed costs raise the barriers to entry. Industry reports describe concentrated reinsurance markets in areas heavily exposed to natural disasters [82]. These frictions provide a natural justification for public interventions that directly expand supply through public reinsurance. Moreover, the need for the public program to conduct its own risk modeling, which could then be made freely available, might further lessen the costs of entry and increase competition.

2.5. Concentrated Losses, Capital Constraints and the Reinsurance Underwriting Cycle

Insurance and reinsurance markets are constrained by the cost and availability of risk-bearing capital. An insurer or reinsurer must hold enough capital to credibly meet policyholder claims especially when a correlated disaster strikes. Even when there has been no change regarding the expected levels of risk, when there is a shock to capital, insurers and reinsurers reduce their supply of insurance and raise prices. This results in the well documented 'underwriting cycle' ([44]). From a social perspective, whether a household is optimally insured should depend only on their willingness-to-pay for insurance and the marginal cost of insuring them, not larger shocks to capital. An inflow of public capital can increase welfare to the extent it expands insurance access to those with a willingness-to-pay that exceeds cost.

These issues are especially pernicious in catastrophe-exposed insurance and reinsurance. Natural catastrophes are large, correlated events that can wipe out a large portion of global risk-bearing capital. Concentrated losses can arise in ways other than direct spatial correlation. Catastrophe risk is difficult to estimate and relies on complex models of a dynamically evolving climate. This generates model risk in which the overall frequency of catastrophes can be underestimated, leading to an unexpected concentration of losses. Regardless of the exact cause, concentrated losses translate to highly cyclical reinsurance prices ([45]). This often leaves primary insurers highly exposed: thinly capitalized homeowners' insurers in high-risk states have often gone bankrupt. These provide a strong rationale for public intervention that explicitly adds to the supply of capital that bears the most correlated tail risks.

2.6. Implications for Public Re/Insurance

The primary market failures in catastrophe-exposed insurance relate to a lack of capital and competition relative to the concentration of risks. There are multiple ways a government might try to increase the supply of capital. The government could relax capital requirements, although this would increase bankruptcy risk and add to charity hazard if the government must provide ex-post assistance to the customers of insolvent insurers. The government could create contingent-liquidity facilities analogous to those that already exist for banks in the US and EU [28]. Although interesting in theory, this has never been trialled, and therefore is hard to evaluate.

The most frequent public intervention that has occurred in insurance markets is

the direct provision of insurance by governments. Some examples (but by no means exhaustive) are listed in Section 4. In the next section, I discuss the ways in which such direct provision has worked and the ways in which it has not. More recently governments have experimented with interventions that provide public reinsurance – insurance for insurers – rather than direct insurance. After concluding that private provision has failed to address some of the most important market failures, the remainder of the paper reviews these public reinsurance programs and their key design choices.

3. Historical Interventions in Insurance Markets

Catastrophe-exposed insurance markets are not functioning well. This has been the case for many decades, with government intervention in insurance markets dating back to at least the 1930s,[8] with programs such as US Crop Insurance or Flood Insurance established over 50 years ago to counteract private market failures. There are ample reasons why public intervention might be justified. But what form should that intervention take?

3.1. Direct Government-to-Household Insurance

The most prevalent form of direct intervention has been government provision of insurance—from unemployment insurance to Social Security to publicly provided flood or farm insurance. The direct provision model has clear advantages and disadvantages.

Direct public provision of insurance has obvious strengths. Public insurance can ensure widespread availability where there might otherwise be a missing market or excluded groups. The New Zealand Earthquake Commission (EQC), US flood insurance (NFIP) and US farm insurance (FCIP) have generated widespread availability (greater than 90% of the relevant market) where historically the private market was unwilling to supply.[9] Almost universal penetration is also observed in the Spanish CCS and the Swiss CIMs[10].

Public insurance can incorporate social objectives into its pricing that a private market would ignore. For example, the NFIP is integrated with the Community Rating System (CRS) in which entire communities are rewarded for risk-reduction beyond the individual home level.[11] Mitigation grants or premium reductions can include benefits for positive

[8] The US Federal Crop Insurance Program was established in 1938.
[9] [78], [80], [58]
[10] [99, 67]
[11] [58]

spillovers of an individual's risk reduction onto their neighbors[12]

Private insurance markets typically require substantial historical claims experiences with which to model risk. This creates a vicious cycle: there is no insurance market, hence no historical claims data, hence no insurance market. Publicly provided insurance can generate this public good that the private market can subsequently use. The decades of loss experience in the NFIP was essential to the now burgeoning private flood insurance market; the earthquake damage data collected by the EQC was integral to national hazard mapping in New Zealand.[13] This provides an important, but time-limited, rationale for initial public insurance provision.

There is mixed evidence on whether public insurance offers more or less operational complexity and administrative costs than private markets. To the extent that public insurance does not incorporate granular risk rating and performs less intensive underwriting than private markets, this can save resources [14]. On the other hand, when private intermediaries are involved in selling an otherwise public system, this can create huge costs [15] A widespread disaster in a program with no intermediaries and direct government administration can lead to substantial delays in claims adjudication and loss remediation.[16]

The primary drawback of public insurance systems has historically been their subsidization of premiums below risk-based levels. This has either been the explicit design goal or a consequence of political pressure.[17] This transfer, from the average taxpayer and/or lower risk insurees to the riskiest insurees, has ambiguous equity implications.[18] However, the efficiency consequences are stark: when households face subsidized insurance prices their risk-reduction decisions (e.g. mitigation and location) are distorted.[19]. Indeed, recent proposals to remove subsidies from various public insurance programs explicitly cite moral hazard as the overriding concern. [20]

[12] [21].

[13] [87, 21]

[14] See [99] for evidence on low administrative overhead in the Spanish CCS, and Canada Mortgage and Housing Corporation [19] which makes the point that the optimal system likely combines the scale of public provision with existing claims-handling and underwriting expertise of the private market.

[15] In the NFIP, over 30% of premium costs are paid as fees to the intermediaries in the program [69, 119].

[16] See, for example, the cautionary tale of the EQC in the aftermath of the Christchurch earthquakes [21].

[17] For explicit subsidies-by-design in the NFIP see [80, 70], in the FCIP see [50, 48, 68]. Subsidies maintained for political reasons have been documented by Kahn and Smith [65], [36, 57].

[18] In the context of the NFIP premium subsidies are somewhere between weakly regressive [11] and distributionally neutral [52]. In other settings such as France, where coastal properties are generally owned by wealthy households, subsidies or solidarity pricing are highly regressive [10].

[19] A large literature demonstrates that subsidized premiums blunt incentives for risk-reduction or risk-avoidance measures. See, for example, the effects of flood insurance on location and mitigation decisions in the US [52], France and Germany [61], for earthquakes in New Zealand [107, 89]

[20] Recent reforms of the NFIP were directly motivated by moral hazard reduction [70, 86].

3.2. A path forward

In light of the market failures cataloged in Section 2, it is perhaps unsurprising that direct government provision of insurance to households has had mixed outcomes. Moral hazard in mitigation and location choices is the first-order concern, as is depressed insurance demand due to expectations of ex-post aid and the capital constraints that result from the spatially correlated nature of natural catastrophe risk. In practice, direct public insurance has proven poorly suited to addressing these. Subsidies that distort prices away from providing clear risk signals blunt incentives for household risk reduction; the expectation (and reality) of ex-post encourages development in high-risk locations. The result, across a wide variety of schemes and countries, is that the 'insurance' component of public insurance is often overwhelmed by political considerations and ceases to provide either adequate risk protection or appropriate risk signals.

These limitations, and the correlated, model-uncertain nature of natural catastrophe risk, motivate a different class of public intervention. Rather than interacting directly with consumers, governments can operate further up the risk-transfer chain by providing reinsurance that insures insurers. By concentrating public capital in the tail of the risk distribution, governments can more precisely target the frictions specific to natural catastrophe risk while leaving pricing, underwriting and claims processing in the hands of the private market and adding a layer of political insulation between them and the households who vote for them. Leading public reinsurance programs such as the CCS in Spain, Flood Re in the UK, the ACRP in Australia and the FHCF in Florida aim to supply cheap and stable capital to absorb shocks to the most correlated risk layers while maintaining risk-based pricing and encouraging mitigation. The remainder of the paper studies this emerging model – public reinsurance – and asks how it should be designed.

4. Public Reinsurance Programs

In this section, I assemble a comprehensive set of public reinsurance programs from around the world. I exclude programs that offer direct insurance to households or businesses. I categorize each of them according to the six design choices in which there is the most disagreement.

a. Who is being reinsured?
   - Typically: primary insurers selling homeowners, commercial, or agricultural insurance.
   - The reinsurance program sometimes insures direct government insurance schemes,

often run by lower (e.g. state or provincial) levels of government.
    - Governments: some reinsurance programs insure sovereign risk directly.

b. How is the program priced?
    - Actuarially fair means that each policy pays a cost that covers their expected claims.
    - Cross-subsidized means that the program as a whole breaks even but some policyholders pay more and some pay less than their expected claims.
    - Subsidized means that the premiums charged do not cover expected costs.

c. Are mitigation incentives incorporated into the program?
    - Premium discounts are provided for certain mitigation actions.
    - Coverage is made conditional on particular mitigation actions.
    - Direct payments or subsidies for mitigation actions.
    - Reinsurance premiums directly or indirectly are used to fund broader risk reduction at the community or regional level.

d. Is participation required?
    - Mandatory participation means that all insurers in the relevant jurisdiction must participate.
    - Voluntary participation means that the reinsured can choose whether to participate or not but if they do, their entire portfolio of policies must participate.
    - Voluntary participation at the policy level means the reinsured can choose to enroll some policies into the reinsurance program but not others.

e. Which risks are reinsured?
    - Single hazards (e.g. wind, or flood).
    - Multiple hazards.

f. What type of coverage is provided and what triggers a reinsurance payment?
    - Parametric reinsurance means payments are triggered based on objective physical measures (e.g. windspeed, flood depth) regardless of actual damage.
    - Portfolio-level reinsurance covers actual portfolio damages, either a constant quota share or all damages beyond a stop-loss threshold.
    - Policy-level reinsurance covers damages to all underlying household or business policies regardless of the size of the losses to the whole portfolio.

g. How are shortfalls (either transitory or permanent) between claims paid and premiums collected funded by the reinsurance program?
    - Government guarantee means that the program can borrow, or receive transfers, from a central government, typically at the sovereign's cost of funds.
    - Donor recapitalization, especially in developing countries, means that shortfalls are funded by additional donations from development agencies and similar.
    - Bond issuance means that the program can sell bonds, secured against future premium income, into private capital markets to fund any temporary shortfalls.

- A levy means that the program can tax all insurers or policyholders in the relevant jurisdiction, whether or not they are enrolled in the reinsurance program, to cover any shortfalls.

TABLE 1. Design Features of Public (Re)Insurance Programs

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
Africa								
African Risk Capacity (ARC)	Governments	Subsidized	Conditionality	Voluntary	Multiple Natural Hazards	Parametric	Donor Recapitalization	Subsidies and capital originally provided by international aid agencies; no explicit mechanism to fund a shortfall
Australia								
Australian Cyclone Reinsurance Pool (ACRP)	Homeowners Insurers	Cross-subsidized	Premium discounts	Mandatory	Cyclones	Policy-level coverage of all cyclone damage	Government guarantee	-
Australian Reinsurance Pool Corporation (ARPC) – Terrorism	Commercial property insurers	Actuarially fair	None	Voluntary	Terrorism	Portfolio indemnity beyond a threshold	Government guarantee	The legislation that created the voluntary reinsurance pool also made it mandatory for the underlying insurance policies to cover terrorism
Belgium								
Terrorism Reinsurance and Insurance Pool (TRIP)	All insurers	Cross-subsidized	None	Voluntary	Terrorism	Industry indemnity beyond a threshold	Government guarantee	Similarly to the ARPC, the underlying law mandates insurers offer terrorism coverage
Canada								

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TABLE 1. Design Features of Public (Re)Insurance Programs (continued)

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
Federal AgriInsurance Reinsurance	Provincial Governments	Actuarially fair	None	Voluntary	All natural hazards that cause agricultural losses	Portfolio indemnity	Federal government guarantee	The premiums paid by farmers for the primary provincial agricultural insurance are subsidized; the reinsurance sold by the federal government to the provinces is actuarially fair. The direct subsidies feature incentives for sustainable farming practices; reinsurance premiums do not.
Caribbean								
CCRIF SPC (Caribbean Catastrophe Risk Insurance Facility)	Governments and public utilities	Actuarially fair	Minimal	Voluntary	Multiple natural hazards	Parametric	Donor capital	Premiums are technically risk-based but often subsidized by donors. There are technical assistance and some small-grant community mitigation incentives.
China								
China Agricultural Reinsurance Company (China Agri-Re)	Agricultural insurers	Subsidized	None	Mandatory 20% cession	All natural hazards that cause agricultural losses	Portfolio quota share	Government guarantee	Direct farming subsidies do have mitigation incentives; the public reinsurance does not have its own.
China Residential Earthquake Insurance Pool (CREIP)	Property insurers	Actuarially fair	None	Voluntary	Earthquakes	Policy-level indemnity (stepped damage categories)	Government guarantee	Recent reforms added other risks to the pool
France								

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TABLE 1. Design Features of Public (Re)Insurance Programs (continued)

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
Caisse Centrale de Réassurance (CCR)	Insurers	Cross-subsidized	Direct payments and conditionality	Voluntary	Multiple natural hazards	Policy-level quota share and portfolio stop-loss	Government guarantee	Insurers must cover natural catastrophes, but can choose whether to reinsure with the CCR.
GAREAT (French terrorism pool)	Insurers	Actuarially fair	None	Mixed	Terrorism	Portfolio indemnity	Government guarantee	Mandatory cession for large risks; voluntary for smaller risks
Indonesia								
MAIPARK	Insurers	Cross-subsidized	None	Mandatory	Earthquake and related tsunami and volcanic risk	Policy-level stop-loss for specific hazards	No defined mechanism	Insurers are required to offer earthquake coverage and cede a mandatory share if the policyholder elects this coverage.
Italy								
Fondo di Riassicurazione (Italy)	Agricultural insurers	Subsidized	None	Voluntary	Multiple agricultural perils	Portfolio indemnity (stop-loss and quota share)	Government guarantee	Part of a wider agricultural support program that includes direct insurance subsidies.
SACE S.p.A.	Insurers writing commercial policies	Actuarially fair	None	Voluntary	Earthquakes, Floods, Landslides	Portfolio quota-share	Government guarantee	-
Japan								
Japan Earthquake Reinsurance (J.E.R.)	Insurers	Actuarially fair	Premium discounts	Mandatory	Earthquake and related tsunami and volcanic risk	Policy-based indemnity	Government guarantee	The JER formally cedes tail risk to the Japanese government and the private reinsurance market.
Netherlands								

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TABLE 1. Design Features of Public (Re)Insurance Programs (continued)

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
Dutch Reinsurance Company for Terrorism Damages (NHT)	Insurers	Cross-subsidized	None	Voluntary	Terrorism	Policy-based indemnity	State guarantee	The program has a total payment cap of €1 billion; if claims exceed the cap payouts reduce proportionally
New Zealand								
Earthquake Commission (EQC)[21]	Homeowners	Cross-subsidized	None	Mandatory for homeowners insurance policies	Multiple natural hazards	Policy-level 'first-dollar' indemnity	Government guarantee	Unusually, the EQC provides coverage for the first layer of risk; all claims up to $300,000 NZD are covered, the private market sells policies to cover the excess
Norway								
Norsk Naturskadepool (Norwegian Natural Perils Pool)	Insurers	Cross-subsidized	None	Mandatory	Multiple natural hazards	Policy-level indemnity	No explicit mechanism	While the NPPP itself doesn't have explicit mitigation incentives, associated public insurance programs do feature grants for risk reduction.
Spain								
CCS - Natural Hazards Reinsurance	Insurers	Cross-subsidized	Prevention fund	Mandatory	Multiple "extraordinary" natural hazards	Policy-level indemnity	Government guarantee	For extraordinary risks (natural catastrophes, terrorism), the CCS acts as a direct insurer, paying policyholders directly. For agricultural risks, the CCS acts as a reinsurer of the Agroseguro pool. All policies must include the CCS surcharge by law
Environmental Liability / Pollution Risks Pool (Spain)	Insurers writing environmental liability policies	Actuarially fair	Conditionality	Voluntary	Environmental liability	Policy-level indemnity	Shortfalls funded proportionally within the pool	-

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TABLE 1. Design Features of Public (Re)Insurance Programs (continued)

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
Switzerland								
Swiss Public Insurers for Real Estate Reinsurance Pool (IRV / KGV)	Public Cantonal insurers	Cross-subsidized	None	Mandated	Multiple natural hazards	Portfolio indemnity	Cantonal governments	Households must insure with cantonal insurers, cantonal insurers can choose to reinsure with IRV/KGV. Shortfalls are ultimately guaranteed by each cantonal government. Some cantons provide discounts for mitigation, but this is distinct from the federal reinsurance.
Taiwan								
Taiwan Residential Earthquake Insurance Fund (TREIF)	Insurers	Cross-subsidized	None	Mandatory	Earthquake	Policy-level indemnity; total loss only	Pro-rated claims and government guarantee	Separate government programs subsidize mitigation, but unrelated to reinsurance.
Thailand								
National Catastrophe Insurance Fund (NCIF)	Insurers	Cross-subsidized	None	Voluntary	Flood, earthquake, storm	Parametric	Government guarantee	The NCIF operated from 2012-2017.
United Kingdom								
Flood Re	Insurers	Cross-subsidized	Mitigation subsidies	Mixed	Flood	Policy-level indemnity	Industry levies	All home insurers must pay a levy regardless of participation; additional premium for all policies they voluntarily cede to the pool. The Build Back Better allows for £10,000 of funding for resilience measures when repairing flood damage.
Pool Re (UK Terrorism)	Insurers	Cross-subsidized	Premium discounts	Voluntary	Terrorism	Policy-level indemnity	Government guarantee	-

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TABLE 1. Design Features of Public (Re)Insurance Programs (continued)

Program	Who is Re/Insured?	Pricing	Mitigation Incentives	Participation	Which Risks	Payment Trigger / Risk Coverage	Funding a Shortfall	Notes
United States								
Florida Hurricane Catastrophe Fund (FHCF)	Insurers	Actuarially fair	Indirect (construction rating factors)	Mandatory	Hurricanes	Portfolio indemnity	Bonds and levies	In addition to bonds and levies, reimbursements can be prorated if there is a shortfall
Medicare Part D Reinsurance	Health insurers	Subsidized	None	Mandatory	Prescription drug risk	Policy-level indemnity	Government guarantee	-
State health reinsurance programs	Health insurers	Subsidized	None	Mandatory	Catastrophic health costs	Policy-level indemnity	State government guarantee and insurer levies	Some states additionally reimburse for costs associated with specific medical conditions
Terrorism Risk Insurance Act (TRIA)	Insurers	No premiums; funded through post-event levies	None	Mandatory	Terrorism	Industry-level threshold with insurer deductibles	Government guarantee	-

[21] Unlike other programs in this table, the EQC acts as a direct insurer of homeowners rather than a reinsurer of private insurers. The EQC levy is collected by private insurers on behalf of the EQC, and claims are paid directly to policyholders by the EQC.

Public Reinsurance Design Choices

5. Pricing: Risk-based vs cross-subsidized vs public subsidy

5.1. Rationale for Risk-Based Pricing

The central argument in favor of risk-based pricing is that it provides clear price signals about the underlying risk. When risk is reflected in prices, and especially when those insurance prices are capitalized into home values, households and firms can make better informed decisions as to where they locate and the extent to which they must mitigate. Leading examples of risk-based public insurance or reinsurance include the NFIP (post-2022), the CEA, KRI, and the FHCF. Recent empirical work, primarily from public insurance, confirms the relevance of these risk signals to property values and subsequent location and mitigation decisions.[22] While these effects are qualitatively clear, they are quantitatively small (at least to the extent they have been correctly measured). Indeed, as I discuss below and in Section 6,[23] they seem second-order relative to other regulations (e.g., building codes) that mandate or encourage mitigation.

Risk-based pricing is key to a financially sustainable public reinsurance program. By pricing in line with actuarial estimates, the program can cover its expected costs without the need to borrow or be bailed out by the taxpayer. This is the logic behind several successful reinsurance programs such as the FHCF which charges 'actuarially indicated premiums' (albeit at the rating-territory level, with ZIP codes grouped into 25 territories), the CEA, and recent reforms by the NFIP.[24] Indeed, decades of prior subsidies and consequently rising debt by the NFIP to the US Treasury is a cautionary tale.[25] Evaluating whether the risk-based pricing implemented by any of these programs is actuarially correct is difficult owing to the infrequent and changing nature of the underlying risk. There is evidence that, procedurally, the CEA and the FHCF have aimed for the most accurate pricing practicable.[26] The FHCF has built up substantial reserves

[22] Recent and older reforms provide a wealth of evidence, such as [52, 83, 54].

[23] There is often the presumption that risk-based pricing is inextricable from proper mitigation incentives. I discuss this at length in Section 6. In summary: risk-based prices are well positioned to increase mitigation if they help make the need for risk reduction more salient, or if we only consider mitigation incentives that are proportional discounts on premiums. However, to the extent that premiums can simply be lowered in absolute terms by the expected risk reduction a mitigation action generates, or if mitigation incentives operate primarily through building codes or other non-price signals, then proper mitigation incentives can still be embedded in a system without risk-based pricing.

[24] See, for example: [77, 18, 110, 102]

[25] [26, 120, 76]

[26] See, for example: [63, 77, 102, 98].

despite a series of large hurricanes, consistent with risk-based pricing, or at least a lack of obvious subsidization.[27]

The interaction between a public reinsurance program and the private reinsurance market is likely improved via risk-based pricing. The alternative – subsidization of some form – risks causing insurer exit if they cannot compete and remain profitable. This has occurred in many public insurance settings; NFIP ([84]), Florida Citizens ([27]) are leading examples in which the subsidized public insurance has cannibalized the private market or prevented its emergence. Optimistically, when the public market offers coverage against the very worst tail risks, this frees reinsurance market capital to cover the layer of the risk 'stack' that they are suited to [24]. If the public program competes with the private market, the latter may try to adversely select risks against the former (although this problem is arguably made worse with moderate subsidization). This is discussed in more detail in Section 7.

Finally, an additional side effect of risk-based public pricing might arise from the substantial investment in data gathering and hazard modeling that such pricing requires. For example, the Florida Office of Insurance Regulation commissioned the Florida Public Hurricane Loss Model (FPHLM) for use in FHCF pricing and DOI regulation. Subsequently, this model has been used more broadly for pricing by private insurance, as well as by additional regulatory agencies and researchers ([53]). Similarly, the NFIP's decades of flood insurance data was integral to enable the burgeoning private flood insurance market and as inputs to the cutting-edge flood-risk models that have recently emerged ([123]). More generally, international evidence emphasizes that catastrophe models and loss data can inform and catalyze climate awareness, adaptation and investment beyond the insurance sector.[28]

5.2. Rationale for Cross-subsidization

An alternate pricing model aims for the fiscal neutrality of the overall public insurance program but with internal cross-subsidies: high-risk homes pay less than their actuarially fair price, low-risk homes pay more. This model aims to combine fiscal sustainability with social solidarity and increased penetration among high-risk homes. A leading example is the UK's Flood Re: insurers cede their high-risk policies to the pool at below-risk prices, which is funded by a uniform levy on all insured houses. This has contributed to widespread availability and price decreases among high-risk properties.[29] Similarly,

[27] [102].
[28] See, for example: [112, 93, 49].
[29] [40, 38, 13, 41]

the Spanish CCS has achieved near universal market coverage (greater than 90%) combined fiscal sustainability though with a comparable cross-subsidy design ([91]). Other programs that are designed with cross-subsidies include the CCR in France, the New Zealand NHI, and the Norwegian NPPP. Although not ideal in the long-term due to the blunted risk signals, this might be a political feasible short-term solution that allows for gradual movements toward risk-rated pricing for existing residents.

5.3. Rationale for Overall Subsidization

A subsidized public program – in which total costs are expected to exceed premiums collected – has numerous downsides. These include moral hazard owing to dulled signals of risk and a lack of fiscal sustainability, as discussed in Section 5.1. Nevertheless, a subsidy can be justified in two cases: correcting externalities and addressing equity concerns.

When a household lacks insurance there are externalities to others that a subsidy could correct. When a household is affected by a disaster and does not have insurance this spills over to decrease their neighbors' property prices [46, 15], can contribute to business closures and local economic slumps [14], increase mortgage default [73, 115] and affect the availability of credit, as well as impose stress on the local public finances [64, 90, 94]. In these cases correcting the externality is a standard Pigouvian rationale for subsidizing insurance or reinsurance.

Relatedly, in many cases governments already provide many forms of ex-post assistance after disasters. This includes FEMA's Individuals and Household Program (IHP) in the US, Australia's Government Disaster Recovery Payments and short-term Disaster Recovery Allowance, and Canada's Disaster Financial Assistance Arrangements which reimburse a share of eligible provincial recovery costs. Increased ex-ante insurance would reduce the ex-post fiscal expenditures. This can rationalize a subsidy for insurance or reinsurance. For example, [52] find that the spillovers from the NFIP to FEMA disaster assistance are large enough to justify NFIP premium subsidies of over 40%.

Finally, if catastrophe exposure or insurance expenditures are disproportionately borne by poorer households, a subsidy might have favorable equity consequences. The UK's Flood Re offers both a justification for and caution against this view. Underlying flood damages are disproportionately borne by poorer households ([30]). Despite this, insurance takeup strongly correlates with wealth in the UK [30, 96] and generally ([51]). As a result, the subsidies implicit in Flood Re mechanically flow to richer households, as do the spillovers such as increased house prices ([47]). This is consistent with weak evidence from the NFIP that subsidies have any markedly progressive effect ([52]). The

overall picture for the equity effects is murky, at best.

6. Mitigation Incentives

In addition to providing protection against natural disasters, public reinsurance should be designed to reduce risk in the longer term. There are three primary mechanisms to do so: premium discounts or contracting incentives for household mitigation, direct grants for mitigation, and building codes and land-use regulation. The former can be naturally embedded into a public reinsurance program, the latter is somewhat orthogonal but public reinsurance eligibility could be conditioned upon it.

6.1. Individual Premium Discounts or Contract Differentials

The premiums that insurers pay on behalf of their enrolled household policies can incorporate discounts for mitigation. In principle, this can include discounts for actions that reduce the risk of the insured household (e.g. elevating a flood-exposed house) and actions that reduce spillovers onto others (e.g. reducing wildfire risk through defensible space). For example, the ACRP offers proportional premium discounts for specific mitigation actions (roof retrofits, window protection etc) ([6]). These standardized discounts are being incorporated by insurers into their household-facing premium formulae ([22]). Nevertheless, there is not yet strong evidence that mitigation has increased as a response, with only $5.8 million in discounts given relative to over $500 million in premiums. The CEA offers a hybrid premium discount and direct payment through the "Brace + Bolt" program in which policyholders receive up to $3,000 and up to a 25% premium discount to retrofit their house [17]. Additional programs with premium-based mitigation incentives include the JER ([81]). Florida's regulatory framework separately mandates that insurers offer household-level wind mitigation discounts, and the FHCF's ratemaking formula reflects construction characteristics that indirectly reward mitigation at the reinsurance level ([102]).

6.2. Direct Payments for Mitigation

A clear limitation of premium incentives is that they require households to pay for costly mitigation today in return for a future stream of reduced premiums. If households are credit constrained, they might not be able to undertake projects even if the premium discounts, in NPV terms, should be sufficient. To overcome this, some public insurance

and reinsurance programs offer direct upfront payments to assist with mitigation. For example, in addition to reimbursing actual losses, Flood Re's "Build Back Better" program offers up to £10,000 per claim to fund approved resilience upgrades ([39]). Similarly, in the context of direct public insurance, the NFIP features Increased Cost of Compliance coverage, which provides for up to $30,000 on top of claim costs to fund elevation or code-mandated mitigation. In the latter case, take up has been low ([71]). It is largely an open question as to whether premium discounts or direct payments are more effective at incentivizing mitigation and raising risk awareness.

6.3. Compliance Conditionality

Finally, and more speculatively, public reinsurance eligibility could be tied to stricter building codes or other risk-reduction actions. To my knowledge, no existing public reinsurance programs feature this linkage. However, the NFIP does require enrolled communities to adopt minimum floodplain management standards [35]. Building codes in general seem to provide better mitigation incentives than premium incentives, likely because the former can be sharply enforced [85, 108]. The closest analogue at the level of reinsurance is the ARC's requirement that member countries have disaster plans in place to be eligible for payouts. There is evidence that this increased pre-disaster preparedness [97]. More broadly, linking public reinsurance eligibility to the adoption and enforcement of modern building codes could be a powerful mechanism for risk reduction. The CCR in France conditions coverage on the declaration of a natural catastrophe by interministerial decree, which in turn requires municipalities to have adopted risk prevention plans (Plans de Prévention des Risques Naturels, PPRn). Municipalities that fail to adopt mandated PPRns can face higher deductibles under the CatNat system, providing a direct financial incentive for community-level compliance [101]. This linkage between reinsurance and regulation remains underexploited.

7. Mandatory vs Voluntary Participation

One of the most important design choices is whether or not to compel insurer participation in the public reinsurance program. Many programs, such as the FHCF, CCS and the ACRP, require all insurers to participate. In contrast, voluntary programs such as Pool Re, or the CCR, only allow insurers to enroll their entire portfolio of risks or none at all. Finally, Flood Re is the leading example of a program in which insurers can choose exactly which policies are in the program. All of these approaches have distinct advantages and disadvantages.

7.1. Mandatory Participation

The primary justification for mandatory participation is that it leads to a broad risk-pooling and diversification and prevents insurers selectively enrolling risky policies or reinsurers cream-skimming favorable risks. The leading examples are the FHCF and Spanish CCS, both of which have achieved high penetration ([91]). In contrast, there is evidence from the French CCR that, prior to a reform that mandated participation, there was substantial adverse selection that contributed to the program's fiscal deficits. The extent to which selection is possible by insurers or reinsurers depends critically on whether they have better information or modeling capacity than the government program.

Relatedly, by removing one margin of choice from insurers, mandatory participation leads to more stable and predictable funding. This ideally reduces the possibility of large fiscal deficits that require levies to be collected or debt to be issued. This has proven to be the case for the Spanish CCS which has never had to use the central government guarantee due to its compulsory and widespread penetration ([78]). Similarly, despite a recent cyclone, the mandatory Australian ARPC found that its premium rates were adequate, and short-term deficits could be met by future premium income [5]. However, mandatory participation is not itself sufficient for fiscal solvency. Mandatory participation when paired with deep subsidies can cause even larger fiscal deficits, as recent years of French CCR experience illustrates ([82]).

7.2. Voluntary Participation (Portfolio Opt-in)

The primary advantages of a voluntary program, where insurers can choose to enroll their entire portfolio into the program or not enroll at all, are that it does not displace the private reinsurance market, encourages competition, and imposes market discipline on the public scheme. This was the explicit rationale behind the UK's Pool Re, in which a small portion of risk is now reinsured privately or securitized [55]. However, the extent to which the market can actually exert discipline on a voluntary public program depends critically on the pricing. If the public program is explicitly subsidized, or offers an implicit cost advantage by not charging a risk premium or profit margin, the opportunities for the private market to compete are minimal [92]. Instead, the private market can remain relevant through a careful construction of *which layer in the risk stack* the public program insures, as I discuss in Section 9.

7.3. Voluntary Participation (Policy Opt-in)

A final, relatively rare, model is to allow insurers to enroll some but not all of their policies in the public reinsurance program. The leading example is the UK's Flood Re. There is evidence that this has led to substantial adverse selection, with only the riskiest policies enrolled [111]. Because Flood Re is designed to cross-subsidize these policies, this is not necessarily detrimental. Additionally, policy-level opt in adds to administrative complexity. Insurers must make a policy-by-policy decision, and might then need to seek private reinsurance on the residual (endogenously chosen) set of retained policies. This was acknowledged in the design of Flood Re as contributing to large administrative costs [31].

8. Which Risks Are Reinsured?

There are three broad ways to define the risks being publicly reinsured. First, the program can cover damage from a specific hazard such as floods or cyclones within a broader insurance product like homeowners insurance. Second, the program can cover many such natural catastrophes, triggered by an event analogous to a US Presidential Disaster Declaration. Third, the program can reinsure a portfolio of, e.g., homeowners insurance policies against excess loss regardless of the cause of loss. The delineation of risks covered is tightly intertwined with the definition of the reinsurance payment trigger, which I discuss in Section 9.

8.1. Single Hazard Designs

Public reinsurance against single hazards allow for simpler design, easier modeling and more direct targeting. Leading examples include Flood Re, which reimburses homeowner insurers only for flood damage, the FHCF which reinsures a portion of hurricane damage in Florida, and the ACRP which covers cyclone damage to Australian insurers. These programs can rely on a well-developed commercial and academic catastrophe modelling ecosystem without needing to fully replicate reinsurance pricing technology. The FHCF notes that this simplifies the administrative burden relative to a multi-hazard program ([9]). Indeed, it is well known that multi-hazard models, especially those that need to account for potentially correlated "secondary-perils" are substantially more complex ([116]). Single-peril programs also allow for an easier definition of the payout trigger: earthquakes can be defined as damages arising in areas that experienced a certain level of seismic activity;

cyclones can follow the declarations made by meteorological agencies ([7]). Relatedly, single-hazard programs can target the exact types of risk that are most problematic to private markets. This efficiently uses public resources. Finally, mitigation incentives can be embedded transparently when there is a clear mapping from risk-reducing action to reduced cost of a single hazard, as opposed to a complicated portfolio problem in which the contribution of one property to the expected reinsurance cost is opaque.

8.2. Multiple Hazard Designs

A natural extension is a reinsurance program that covers many or all natural disasters while leaving idiosyncratic, non-catastrophe risk in the remit of the primary insurer. A primary benefit is diversification across perils and regions. Depending on the relative strength and correlation of exposure, pooling multiple hazards into one program can reduce the volatility of payouts. Naturally, the greater the size of areas and number of hazards pooled together, the more diversification benefits accrue. Leading examples are the French CCR and Spanish CCS, which cover all natural catastrophes once an official declaration is made [91]. An added advantage of including multiple risks and multiple regions is that it might broaden the political support for the public program, so that regions exposed to particular hazards are not disproportionately advantaged or disadvantaged.

Closely related is the fact that attributing damages to specific perils is often difficult. Insuring them all at once removes the need to differentiate or potentially manipulate this attribution. For example, hurricanes cause wind damage and water damage which are often covered by separate insurance or reinsurance programs ([118]). These ambiguities can increase uncertainty and reduce trust in insurance ([1]). This can be somewhat alleviated by defining coverage in terms of a single underlying event (e.g. a hurricane) rather than the specific type of damage (e.g. wind damage).

8.3. Portfolio Stop-loss Designs

An alternative to hazard-specific coverage is to reinsure losses on an insurance portfolio, after a threshold, regardless of the cause. This would cover all natural disasters but would also include losses from idiosyncratic causes such as theft or arson. The primary benefit of this design is that it mimics the typical contract structure that is prevalent in private reinsurance ([113]). If the public program wrote similar contracts this would lessen the burden on insurers, who are already used to such modeling ([91]). It would maintain private market competition and discipline, and it would allow for transparent integration into

insurer's balance sheet and capital adequacy management, which already rely on whole-portfolio excess-of-loss measures ([34]). Moreover, by setting an appropriate threshold, below which insurers retain exposure, moral hazard in terms of lax underwriting or poor claims processing can be lessened relative to a hazard-specific program that covers any losses caused.

These advantages have corresponding disadvantages. The government would have to build up the modeling capacity equivalent to private reinsurers (which may have many more years of data and experience to work with); the public program cannot solely rely on catastrophe models that are independently available. Similarly, while insurers might have minimal control or scope for moral hazard when it comes to well-defined natural catastrophes, including all other risks in the portfolio might cause costs to increase due to the more generous reinsurance protection. A cautionary tale comes from medical reinsurance, in which excess-of-loss portfolio reinsurance led to cost blowouts ([79]). There are no existing public reinsurance programs that insure losses at the portfolio level. This might speak to the difficulty or lack of desirability of this structure, relative to the targeted and well-defined focus on catastrophe losses.

9. Reinsurance Payment Trigger and Risk Coverage

Closely intertwined with the discussion in Section 8 is the choice of what triggers payments in the reinsurance program. There are three broad categories: parametric triggers and payment definitions, indemnity-based trigger at the policy or portfolio level, or an event-based trigger.

9.1. Parametric Trigger

Parametric public reinsurance ties payouts to an objective index (for example, wind speed, ground movement, or rainfall) rather than directly to losses. It has been widely adopted by reinsurance *for governments* or regional groups of governments; it is less common in reinsurance programs run by governments for their domestic insurers. For example, Mexico's FONDEN layers were funds made available by the central government for reconstruction and rehabilitation works and financed by parametrically-triggered catastrophe bonds. The primary benefits are the low costs and quick payments: no actual damages have to be assessed, and payments can be processed rapidly after the physical parametric trigger is activated ([106]). An additional benefit, particularly relevant to governments, is that a non-trivial portion of damage is not directly attributable to physical damage. For

example, lost tourism revenue and increased public recovery expenditures ([117]). Some or all of these non-physical losses can be covered by parametric payouts.

The primary downside of parametric insurance is basis risk: the fact that there is an imperfect correlation between the parametric trigger and the underlying losses against which insurance is needed. Many empirical studies have found basis risk to be substantial and the primary reason why demand for parametric products at the household level is low ([20]). Improved modern modeling can potentially reduce basis risk. This can be through more localized trigger definitions (e.g. wind speed at each house's latitude and longitude as opposed to a spatial average). However, as the trigger becomes more specific and costly to monitor, the initial benefits of parametric insurance – simplicity and speed – might be inhibited. Overall, parametric insurance is best used as a top-layer risk management tool, perhaps a funding strategy for public reinsurance, rather than as the primary means of risk protection.

9.2. Where in the Risk Stack?

Even once a program decides to indemnify actual losses, it must decide where in the risk stack the public reinsurance layer should sit. The vast majority of public reinsurance programs are 'last-dollar' protection: they are activated only for very large event or portfolio losses, with all but the most catastrophic losses covered by insurers or borne by households. Leading examples of portfolio last-dollar coverage include the FHCF, which provides excess of loss layer that varies based on industry exposure ([104]). Relatedly, the French CCR provides unlimited reinsurance above insurers' own retentions only for officially declared disasters. The main advantages of last-dollar programs are targeting and incentives. By focusing protection on the most catastrophic states, the insurance value per dollar of public expenditure is maximized. Moreover, by ensuring insurers retain significant exposure, their incentives to remain efficient in their underwriting and claims processing are maintained.

An alternative is the 'first-dollar' approach of the New Zealand NHC. The NHC provides mandatory reinsurance for the first layer of risk (up to $150,000-$300,000 NZD) with private insurers responsible for anything beyond that ([88]). This has led to wide penetration of the NHC, and simple integration into insurer pricing and administrative systems ([62]). This success is likely due to the cross-subsidized, non-risk-rated nature of NHC pricing. A first-dollar design is more appropriate when the goals are widespread affordability, participation and solidarity rather than accurate risk signals and improved mitigation.

10. Funding a Shortfall

As discussed in Section 5 public reinsurance programs can either be designed to be self-funding or feature explicit subsidies. In the latter case, deficits between premiums collected and claims paid will arise by design. But even in the former case, because of the irregular nature of catastrophes, even a fiscally solvent program may have to pay out large losses before it has collected enough premium reserves to finance these. In this section, I discuss different approaches to financing these deficits, whether they are temporary or structural.

10.1. Emergency Levies

Many public insurance and reinsurance programs finance deficits through industry levies. For example, Spain's CCS imposes surcharges on a wide variety of insurance premiums, both catastrophe-exposed and not; the FHCF uses emergency assessments to fund shortfalls (as well as pre- and post-event bonds). The main advantage is their reliability: levies provide access to a vast funding pool. This allows public reinsurance programs to maintain high credit ratings, providing a natural complementarity between the *option to levy* and the cost of issuing post-event debt. This is most salient in the case of the FHCF, which can issue emergency levies of up to 6% per year on most property and casualty premiums. When the FHCF did levy assessments after the 2005 hurricane season, the rate was only 1.0–1.3%, well below the statutory cap, and was retired ahead of schedule. More broadly, the credibility of such levies has allowed the FHCF to issue post-event bonds at low cost due to its high credit rating ([43]). This is perhaps the best use of levies: as an implicit backstop that lowers the cost of borrowing but never has to be used.

The downside of levies that are actually used is clear: they are imposed at exactly the time the private market is least capable of paying them, and turn even a purportedly actuarially fair program in a cross-subsidy. Levies issued in the wake of a catastrophe accentuate the high insurance and reinsurance prices that arise from the well documented underwriting cycle [44, 45] that was a justification for public intervention in the first place. Additionally, when levies are imposed on all insurance policies in a jurisdiction to pay for losses incurred from natural disasters, this is a direct transfer from the low-risk to the high-risk. This, de facto, acts to dilute price signals by dissociating price from risk. Often this is the explicit goal: the Spanish CCS, French CCR, NZ NHI all operate under a framework of social solidarity in which disaster costs are borne by the whole of society. For all the reasons discussed in prior sections, this will accentuate moral hazard and ultimately add to the disaster costs that society must bear.

10.2. Borrowing or Transfers from the Central Government

A second way to finance reinsurance deficits, whether transitory or structural, is to borrow or receive transfers from the central government. The primary advantage, especially relative to direct post-event bond issuance, is the central government's lower cost of borrowing. This is usually due to central government being substantially more diversified than the reinsurance program, as well as any convenience yield that government debt attracts. Programs such as the NZ NHC, Australian ARPC, and Japanese JER implicitly have this government guarantee as their funding option of last resort, thereby relying on the sovereign balance sheet to smooth catastrophe losses over time.

By construction, this is an implicit or explicit transfer from the taxpayer to those who suffer catastrophe losses. Explicit if the program runs a structural deficit due to subsidized premiums; implicit in that even a fiscally balanced program that will pay back its loans to the central government imposes some risk and an opportunity cost of capital on the taxpayer. Most programs that borrow from the central government do so at the government's cost of funds, with no risk adjustment. Moreover, although not inevitable, there has been a tendency for debt to become a transfer. For example, NFIP debts have on occasion been cancelled by Congress—most notably the $16 billion write-off in 2017 [56]. Forgiving debt causes the program to be ex-post subsidized, even if the original design called for fiscal balance. To the extent a central government guarantee risks these distortions after the fact it should be factored in.

10.3. Pre- or Post-Event Bond Issuance

Instead of relying on post-disaster levies or central government assistance, some public reinsurance programs issue catastrophe bonds or other insurance-linked securities ex-ante to defray costs should a catastrophe occur, or smooth incurred catastrophe bonds over time by issuing revenue bonds backed by future premiums or levies ex-post. Pre-event catastrophe bonds and reinsurance purchases are used by Mexico's FONDEN, the US NFIP, and other national governments. The clear advantage is that the reinsurance program bears less risk. But the very point of the reinsurance program is to bear risk more efficiently than the private markets it is supposedly needed to replace. By transferring some of the catastrophe risks back in to the private market, and paying private market prices to do so, it undermines the core rationale for the program's existence.

More defensible is the use of post-event bonds secured against future premiums to finance catastrophe losses. As compared to central government borrowing or jurisdiction-

wide levies, post-event bonds ultimately keep the catastrophe costs within the reinsurance program, yet allow them to be smoothed over time. Leading examples of these are the Florida Citizens insurance and the FHCF reinsurance programs. Both have repeatedly issued bonds to be repaid out of future premiums and levies [42]. As noted above, there is a natural complementarity between post-event bonds and the *option* to impose levies. Post-event bonds can be issued cheaply, and levies therefore minimally used, so long as the market believes that the possibility to issue levies is credible if needed ([74]). This might optimally combine the 'user-pays' advantage of post-event bonds with the taxation or levy power of a public institution.

11. Implications for a U.S. Public Reinsurer

U.S. catastrophe-exposed insurance markets are in crisis. Premium increases, policy non-renewals, insurer exits, and the swelling of state-run insurers of last resort are now widespread across hurricane, wildfire, and flood-exposed states.[30] These trends have intensified a longstanding policy debate about the appropriate federal role in catastrophe insurance markets. Proposals for a federal catastrophe reinsurer are not new — the Congressional Budget Office evaluated the concept in 2002, and legislation such as the Natural Disaster Protection Partnership Act of 1995 proposed a federal natural disaster insurance corporation.[31] More recently, this conversation has been catalyzed by new proposals, including the INSURE Act[32] and the proposal by Collier, Keys, and Mulder [24] for a federal property reinsurer, which they term US Re. In this section, I discuss the US Re proposal in light of the global evidence assembled in the preceding sections.

The US Re proposal envisions a federal entity that sells reinsurance contracts to U.S. homeowners insurers and reinsurers to cover the most severe tail of the catastrophe loss distribution, explicitly at a layer above what private reinsurers are willing or able to cover at sustainable prices. Correlated catastrophe risk — particularly the most extreme tail events — generates capital frictions that private markets cannot efficiently bear: reinsurers must hold large amounts of equity against low-frequency, high-severity events, and their cost of capital rises sharply and cyclically after large losses. The federal government, able to borrow at lower rates and diversify catastrophic risk across the public balance sheet, can bear these tail risks at a lower and more stable cost.

US Re is designed not to replace the private market but to hold the extreme tail, freeing

[30] [66, 105, 12, 37]
[31] [25, 121]
[32] [95]

private capital to compete across the remainder of the risk distribution and crowd in, rather than crowd out, private participation. Three design principles guide their proposal: price risk accurately at the property level; target the specific market failures arising from correlated tail risk rather than expected losses; and maintain sufficient institutional independence from political pressure to credibly commit to actuarially sound pricing. On the question of program structure, Collier, Keys, and Mulder leave several important design dimensions open. Most notably, whether participation should be mandatory, whether contracts should operate at the policy or portfolio level, and how mitigation incentives, if at all, should be incorporated.

The core frictions that US Re diagnoses are broadly consistent with the global evidence and experience reviewed here. Capital frictions arising from correlated tail catastrophe risk are, as I have argued, the most important and actionable source of market failure. The private reinsurance underwriting cycle is well-documented[33] and the evidence from the ACRP — the most direct empirical test available — indicates that a public reinsurer priced without a full cost-of-capital markup can reduce primary insurance premiums by roughly 20 percent and expand availability by around 11 percent, with the majority of gains attributable to eliminating the correlated-risk markup rather than any subsidy.[34] The US Re proposal correctly focuses on this layer of risk, and the global evidence makes this the most compelling available rationale for a federal public reinsurer.

The decision to operate as a reinsurer rather than a primary insurer is similarly well-supported. As I discuss in Section 3, the primary pathology of direct public insurance has been the politicization of pricing: programs that set rates for households are highly salient to voters and to the legislators who authorize them, generating persistent pressure to subsidize premiums below actuarially fair levels. The NFIP is the cautionary tale, having accumulated over $22 billion in Treasury debt as of 2025, but similar dynamics have emerged in many public insurance programs globally. By operating one step removed from the household — reinsuring insurers rather than insuring households — a public reinsurer introduces a layer of political insulation that is directly analogous to what has made programs like the Spanish CCS and the FHCF more fiscally durable than the NFIP. The comparison is instructive: both the CCS and the FHCF maintain actuarially indicated pricing and have accumulated reserves despite a series of large events, while the NFIP has repeatedly required congressional intervention.

A subtle tension arises from the US Re proposal's preferred contract structure. Collier, Keys, and Mulder propose portfolio-level excess-of-loss reinsurance — covering aggregate

[33] [44, 45]
[34] [109]

insurer losses above a high attachment point — arguing it best mirrors existing private reinsurance contracts and would ease integration into insurers' capital management. This is a reasonable starting point, and a well-designed portfolio stop-loss contract could in principle incorporate geographic concentration, correlation structure, and other portfolio-level risk factors into its pricing.

The fundamental difficulty is that under a portfolio stop-loss structure, the reinsurance cost attributable to any individual policy depends not only on the characteristics of that policy alone, but on the composition of the portfolio in which it sits. This makes it difficult to translate the reinsurance price into a meaningful, property-level signal for the primary insurer — and still harder to embed the kind of specific mitigation incentives discussed in Section 6. A premium discount for elevating a flood-exposed home, for example, requires a clear mapping from that action to a reduction in reinsurance cost; under aggregate portfolio coverage, that mapping is obscured. Policy-level indemnity coverage — the structure used by the majority of public reinsurance programs in Table 1, including the ACRP, Flood Re, and the JER — preserves this link, making it considerably easier to incorporate risk-based pricing at the household level and to reward individual mitigation actions with meaningful premium reductions.

The most significant gap in the US Re proposal is the near-absence of mitigation incentives. Collier, Keys, and Mulder note that the portion of premium increases reflecting rising expected losses should be preserved as a signal for household risk reduction and location decisions, and they suggest that mitigation be addressed through separate, complementary policies rather than embedded in US Re's design. I am sympathetic to the argument that the primary goal of US Re is to address capital market failures rather than correct moral hazard. Nevertheless, as I argue in Section 2, moral hazard in mitigation and location choices is one of the most important frictions in catastrophe-exposed insurance markets, and one that public reinsurance design is well-positioned to address — or to inadvertently exacerbate. Moreover, [24]'s stated goal that US Re accurately price risk should extend not only to static risk but to the accurate pricing of risk-reducing actions. A portfolio stop-loss structure, in particular, severs the link between individual property risk reduction and the reinsurer's cost, blunting the mitigation price signal at the very layer where it matters most. Leading programs such as Flood Re, the ACRP, and the CEA have each found ways to embed premium discounts for verifiable mitigation actions within risk-based pricing frameworks.[35] Flood Re's "Build Back Better" provision goes further, conditioning additional payments on resilience investment at the point of a claim.[36]

[35] [102, 6, 17]
[36] [39]

Finally, the question of mandatory versus voluntary participation, which Collier, Keys, and Mulder acknowledge but leave partially unresolved, warrants emphasis. The global evidence reviewed here provides consistent support for the view that adverse selection is a serious threat to the fiscal sustainability of voluntary reinsurance programs. The French CCR's experience prior to effective mandatory participation provides the clearest case study: insurers with favorable portfolios declined to cede, leaving the program with a disproportionately risky pool and contributing to persistent deficits.[37] The programs with the strongest track records — the CCS, the FHCF, the ACRP — are uniformly mandatory.[38] Against this, Collier, Keys, and Mulder express concern that mandatory participation risks crowding out private reinsurers — a legitimate concern, but one that is best addressed through careful calibration of attachment points rather than through voluntary opt-in. The FHCF's blended approach, in which participation is mandatory but the degree of coverage is variable, offers a promising template: it achieves wide pool diversification while preserving some insurer choice at the intensive margin.

12. Conclusion

Natural catastrophe insurance markets feature a familiar set of market failures, but in unusually acute form. Correlated tail losses amplify capital constraints and underwriting-cycle dynamics; moral hazard and externalities distort mitigation and location choices; and charity hazard depresses insurance demand. The historical policy response—direct public provision of insurance—has often expanded availability, but has repeatedly struggled with politicized pricing, distorted incentives, and fiscal instability. These limitations have motivated a distinct and increasingly common intervention: public reinsurance, in which governments supply capacity in the tail of the loss distribution while leaving underwriting, pricing, and claims administration largely to private insurers.

This paper assembled a comprehensive catalog of global public reinsurance programs and organized them around the core design choices on which programs differ: who is reinsured, how premiums are set, whether and how mitigation is incentivized, whether participation is mandatory, which risks are covered, what triggers payments, and how shortfalls are financed. The cross-country record suggests that these choices are not cosmetic. The most successful programs tightly target correlated tail risk, maintain credible and transparent funding backstops, and explicitly grapple with adverse selection and incentive distortions. Programs that instead blur the boundary between risk financing and social transfers tend to dilute risk signals and invite political pressure that undermines

[37] [91]
[38] [78, 102, 5]

long-run sustainability.

For the United States, the international evidence points to a clear direction but not an unambiguous template. A federal reinsurer is most likely to improve welfare if it is designed as a narrowly targeted tail-risk backstop that stabilizes the cost of capital without becoming a de facto primary insurer. The central open questions are design questions: where the public layer sits in the risk stack; whether participation is sufficiently broad to prevent adverse selection; how reinsurance pricing incorporates portfolio concentration and changing correlation; and how the program complements, rather than substitutes for, separate mitigation, land-use, and equity policies. Answering these questions—and committing credibly to the resulting rules—is the difference between a program that repairs a broken tail-risk market and one that recreates the familiar shortcomings of public insurance.

References

[1] Abbott, Ernest B. 2008. "Floods, Flood Insurance, Litigation, Politics – and Catastrophe: The National Flood Insurance Program." *Sea Grant Law and Policy Journal* 1 (1): 129–160. https://nsglc.olemiss.edu/sglpj/Vol1No1/7Abbott.pdf.

[2] Arrow, Kenneth J. 1963. "Uncertainty and the Welfare Economics of Medical Care." *American Economic Review* 53 (5): 941–973.

[3] Australia. Parliament. Senate. Economics References Committee. 2017. "Australia's General Insurance Industry: Sapping Consumers of the Will to Compare." Parliamentary paper series 233/2017, Department of the Senate, Canberra. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Generalinsurance/Report.

[4] Australian Government. 2024. "North Queensland Home Insurance." https://nqhomeinsurance.gov.au/. Accessed: 2024-01-18.

[5] Australian Reinsurance Pool Corporation. 2025. "ARPC Releases 2025 Financial Outlook." https://www.arpc.gov.au/. Press release and accompanying material indicating that cyclone pool claims, including from Cyclone Alfred, are expected to be met from assets and future premiums without calling on the Commonwealth guarantee.

[6] Australian Reinsurance Pool Corporation. 2025. "Cyclone Reinsurance Pool Fact Sheet." ARPC. https://arpc.gov.au/resources/cyclone-reinsurance-pool-fact-sheet/. Last updated July 2025.

[7] Australian Treasury. 2022. "Terrorism Insurance Amendment (Cyclone and Related Flood Damage Reinsurance Pool) Regulations 2022: Explanatory Statement." Explanatory statement to subordinate legislation. https://treasury.gov.au/sites/default/files/2022-02/2021_246322_reinsurance_pool_ES.pdf. Defines cyclone event periods and the role of Bureau of Meteorology declarations.

[8] Baylis, Patrick W. and Judson Boomhower. 2021. "Mandated vs. Voluntary Adaptation to

Natural Disasters: The Case of U.S. Wildfires." NBER Working Paper 29621, National Bureau of Economic Research. 10.3386/w29621.

[9] Beatty, Kyle. 2007. "Overview of the Florida Hurricane Catastrophe Fund (FHCF)." Presentation to the Casualty Actuaries of Greater New York. https://www.casact.org/sites/default/files/old/files_cagny_beatty.pdf.

[10] Bézy, Thomas. 2025. "Real Estate Wealth Inequality and Exposure to Natural Disasters." Working Paper 2025/16, World Inequality Lab, Paris. https://prod.wid.world/www-site/uploads/2025/07/WorldInequalityLab_WP2025_16_Real-Estate-Wealth-Inequality-and-Exposure-to-Natural-Disasters_Final.pdf.

[11] Bin, Okmyung, John A. Bishop, and Carolyn Kousky. 2012. "Redistributional Effects of the National Flood Insurance Program." *Public Finance Review* 40 (3): 360–380.

[12] Boomhower, Judson, Meredith Fowlie, Jacob Gellman, and Andrew Plantinga. 2024. "How Are Insurance Markets Adapting to Climate Change? Risk Classification and Pricing in the Market for Homeowners Insurance." Working Paper 32625, National Bureau of Economic Research. https://www.nber.org/papers/w32625.

[13] Bord, Andy. 2018. "Flood Re: Making affordable home insurance available to those at flood risk in the UK." *Consorseguros Digital* (8). https://www.consorsegurosdigital.com/en/numero-08/contributions/flood-re-making-affordable-home-insurance-available-to-those-at-flood-risk-in-the-uk/. Explains premium design; notes pricing remains sufficiently high so mainly high-risk policies are ceded.

[14] Boustan, Leah Platt, Matthew E. Kahn, Paul W. Rhode, and Maria Lucia Yanguas. 2020. "The Effect of Natural Disasters on Economic Activity in U.S. Counties: A Century of Data." *Journal of Urban Economics* 118: 103257. 10.1016/j.jue.2020.103257.

[15] Box-Couillard, Sebastien and Yilan Xu. 2024. "Does Flood Insurance Help Neighborhoods Recover from Flooding?" Working paper.

[16] Buchanan, James M. 1975. "The Samaritan's Dilemma." In *Altruism, Morality, and Economic Theory*, edited by Edmund S. Phelps, pp. 71–85. New York: Russell Sage Foundation.

[17] California Earthquake Authority. 2025. "CEA Policyholder Brace + Bolt Grants." https://www.earthquakeauthority.com/prepare-your-house-earthquake-risk/brace-and-bolt-grants/cea-policyholder-brace-bolt-grants. Accessed: 1 December 2025.

[18] California Earthquake Authority. 2025. "CEA's Financial Strength." https://www.earthquakeauthority.com/. Accessed November 2025.

[19] Canada Mortgage and Housing Corporation. 2023. "An International Comparative Study of Catastrophe Risk Mitigation and Insurance." Tech. rep., Canada Mortgage and Housing Corporation. https://www.cmhc-schl.gc.ca/professionals/housing-markets-data-and-research/housing-research/research-reports/housing-needs/international-comparative-study-catastrophe-risk-mitigation-insurance. Prepared by Deloitte.

[20] Carter, Michael R, Alain de Janvry, Elisabeth Sadoulet, and Alexander Sarris. 2017. "Index insurance for developing country agriculture: a reassessment." *Annual Review of Resource Economics* 9 (1): 421–438. 10.1146/annurev-resource-100516-053352.

[21] Cartwright, Silvia. 2020. “In the Matter of the Public Inquiry into the Earthquake Commission: Report of the Public Inquiry.” Tech. rep., Public Inquiry into the Earthquake Commission, Wellington, New Zealand. https://www.eqcinquiry.govt.nz/assets/Reports/Report-of-the-Public-Inquiry-into-the-EQC.pdf. This is the final report resulting from the review process initiated in 2017 by the NZ Treasury.

[22] CHU Underwriting Agencies. 2025. “ARPC Cyclone Mitigation Measures.” CHU. https://chu.com.au/cyclone-mitigation/. Describes strata mitigation discounts effective 1 April 2025.

[23] Coate, Stephen. 1995. “Altruism, the Samaritan’s Dilemma, and Government Transfer Policy.” *American Economic Review* 85 (1): 46–57.

[24] Collier, Benjamin L., Benjamin J. Keys, and Philip Mulder. 2025. “A Case for a U.S. Federal Property Reinsurer.” https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4978479. Working paper, October 6, 2025.

[25] Congressional Budget Office. 2002. “Federal Reinsurance for Disasters.” Tech. rep., Congressional Budget Office, Washington, DC. https://www.cbo.gov/sites/default/files/107th-congress-2001-2002/reports/09-20-federalreinsurance.pdf.

[26] Congressional Budget Office. 2017. “The National Flood Insurance Program: Financial Soundness and Affordability.” Tech. rep., Congressional Budget Office, Washington, DC.

[27] Corporation, Citizens Property Insurance. 2024. “Florida Residential Property Market Share — Historical Market Share Report.” https://www.citizensfla.com/documents/20702/93160/20240930+Market+Share+Report.pdf. Citizens’ admitted market share was 23.5% in 2011.

[28] Cummins, J. David and Mary A. Weiss. 2014. “Systemic Risk and the U.S. Insurance Sector.” *Journal of Risk and Insurance* 81 (3): 489–527. 10.1111/j.1539-6975.2012.01505.x.

[29] Davlasheridze, Meri and Qing Miao. 2019. “Does Governmental Assistance Affect Private Decisions to Insure? An Empirical Analysis of Flood Insurance Purchases.” *Land Economics* 95 (1): 124–145. 10.3368/le.95.1.124.

[30] Department for Environment, Food and Rural Affairs. 2013. “Affordability and Availability of Flood Insurance in High-Risk Areas.” Tech. Rep. FD2688, UK Department for Environment, Food and Rural Affairs.

[31] Department for Environment, Food and Rural Affairs. 2014. “Flood Re: Impact Assessment.” Tech. rep., Defra, London. https://assets.publishing.service.gov.uk. Final Impact Assessment for the Water Bill flood insurance clauses.

[32] Deryugina, Tatyana and Barrett Kirwan. 2018. “Does the Samaritan’s Dilemma Matter? Evidence from U.S. Agriculture.” *Economic Inquiry* 56 (2): 983–1006. 10.1111/ecin.12527.

[33] Einav, Liran and Amy Finkelstein. 2011. “Selection in Insurance Markets: Theory and Empirics in Pictures.” *Journal of Economic Perspectives* 25 (1): 115–138.

[34] European Parliament and Council of the European Union. 2009. “Directive 2009/138/EC on the Taking-up and Pursuit of the Business of Insurance and Reinsurance (Solvency II).” Official Journal of the European Union, L 335, pp. 1–155. https://eur-lex.europa.eu/eli/dir/2009/138/oj/eng.

[35] Federal Emergency Management Agency. 2020. “Building Codes Save: A Nationwide Study.”

Tech. rep., FEMA.

[36] Feinman, Jay M. 2025. "Designing Public Solutions for Disaster Insurance Market Failures." *Journal of Insurance Regulation* Forthcoming / early view, NAIC Center for Insurance Policy and Research.

[37] Financial Stability Oversight Council. 2024. "2024 Annual Report." Tech. rep., U.S. Department of the Treasury. https://home.treasury.gov/system/files/261/FSOC2024AnnualReport.pdf.

[38] Flood Re. 2022. "Almost Half a Million Households Have Now Benefited from Flood Re." Flood Re Press Release. https://www.floodre.co.uk/almost-half-a-million-households-have-now-benefited-from-flood-re/.

[39] Flood Re. 2022. "Build Back Better: Funding Property Flood Resilience." https://www.floodre.co.uk/faq/what-is-build-back-better/. Programme overview and eligibility.

[40] Flood Re. 2025. "Flood Re Limited Annual Report and Accounts 2024–2025." Tech. Rep. HC 1019, Flood Re. https://www.gov.uk/government/publications/flood-re-annual-report-and-accounts-2024-to-2025.

[41] Flood Re. 2025. "Written Evidence Submitted to the Environmental Audit Committee Inquiry on Flood Resilience in England." UK Parliament, Environmental Audit Committee. https://committees.parliament.uk/work/8736/flood-resilience-in-england/publications/written-evidence/. Submitted January 2025.

[42] Florida Hurricane Catastrophe Fund. 2024. "May 2024 Estimated Claims-Paying Capacity." Tech. rep., State Board of Administration of Florida, Tallahassee, FL. https://www.sbafla.com/fhcf. Includes discussion of pre-event notes, post-event bonding capacity, and assessment authority.

[43] Florida Hurricane Catastrophe Fund (FHCF). 2025. "Claims-Paying Capacity Estimates, May 12, 2025." Tech. rep., State Board of Administration of Florida. https://fhcf.sbafla.com/media/vs3bdea2/fhcf-may-2025-bonding-capacity-final.pdf. Mandatory participation; actuarially indicated premiums; large, diversified assessment base underpinning bonding capacity (pp. 2, 6).

[44] Froot, Kenneth A. 2001. "The Market for Catastrophe Risk: A Clinical Examination." *Journal of Financial Economics* 60 (2–3): 529–571.

[45] Froot, Kenneth A. and Paul G. J. O'Connell. 2008. "On the Pricing of Intermediated Risks: Theory and Application to Catastrophe Reinsurance." *Journal of Banking and Finance* 32 (1): 69–85. 10.1016/j.jbankfin.2007.09.006.

[46] Fu, Chao and Jesse Gregory. 2019. "Estimation of an Equilibrium Model With Externalities: Post-Disaster Neighborhood Rebuilding." *Econometrica* 87 (2): 387–421. 10.3982/ECTA14246.

[47] Garbarino, Nicola, Benjamin Guin, and Jonathan Lee. 2024. "The Effect of Subsidized Flood Insurance on Real Estate Markets." *Journal of Risk and Insurance* 91 (4): 991–1024. 10.1111/jori.12491.

[48] Glauber, Joseph W. 2013. "The Growth of the Federal Crop Insurance Program, 1990–2011." *American Journal of Agricultural Economics* 95 (2): 482–488. 10.1093/ajae/aas091.

[49] Golnaraghi, Maryam et al. 2021. "Climate Change Risk Assessment for the Insurance Industry:

A Holistic Decision-Making Framework and Key Considerations for Both Sides of the Balance Sheet." Tech. rep., The Geneva Association, Zurich.

[50] Goodwin, Barry K. and Vincent H. Smith. 2013. "What Harm Is Done by Subsidizing Crop Insurance?" *American Journal of Agricultural Economics* 95 (2): 489–497.

[51] Gropper, Michael J. and Camelia M. Kuhnen. 2025. "Wealth and Insurance Choices: Evidence from U.S. Households." *The Journal of Finance* 80 (2): 1127–1170. https://doi.org/10.1111/jofi.13426.

[52] Gruber, Jonathan and Adam Solomon. 2025. "Optimal Flood Insurance in a Second-Best World: Fiscal Spillovers, Reclassification Risk, and Moral Hazard." Working paper, MIT and NYU Stern.

[53] Hamid, Shahid S. 2006. "Florida Public Hurricane Loss Model (FPHLM)." Tech. rep., International Hurricane Research Center, Florida International University. https://eei.fiu.edu/_assets/images/hamid.pdf. Public hurricane/wind-loss model report.

[54] Hino, Mikiko and Marshall Burke. 2021. "The Effect of Information about Climate Risk on Property Values." *Proceedings of the National Academy of Sciences* 118 (17): e2003374118.

[55] HM Treasury. 2021. "Review of Pool Reinsurance Company Ltd." Tech. rep., HM Treasury, London. https://www.gov.uk/government/publications/review-of-pool-reinsurance-company-ltd.

[56] Horn, Diane P. 2017. "National Flood Insurance Program Borrowing Authority." Tech. Rep. CRS Insight IN10784, Congressional Research Service, Washington, DC. https://www.rstreet.org/wp-content/uploads/2018/07/CRS-Insight-NFIP-Borrowing-Authority.pdf. Includes documentation of the $16 billion debt cancellation in 2017.

[57] Horn, Diane P. and Baird Webel. 2022. "National Flood Insurance Program: The Current Rating Structure and Risk Rating 2.0." Tech. Rep. R45999, Congressional Research Service.

[58] Horn, Diane P. and Baird Webel. 2023. "Private Flood Insurance and the National Flood Insurance Program (NFIP)." CRS Report R45242, Congressional Research Service, Washington, DC. https://crsreports.congress.gov/product/pdf/R/R45242.

[59] Hovekamp, Winston P. and Katherine R. H. Wagner. 2023. "Efficient Adaptation to Flood Risk." *AEA Papers and Proceedings* 113: 304–309. 10.1257/pandp.20231103.

[60] Hudson, Paul, W. J. Wouter Botzen, Jeffrey Czajkowski, and Heidi Kreibich. 2017. "Moral Hazard in Natural Disaster Insurance Markets: Empirical Evidence from Germany and the United States." *Land Economics* 93 (2): 179–208.

[61] Hudson, Paul, W. J. Wouter Botzen, Luc Feyen, and Jeroen C. J. H. Aerts. 2016. "Incentivising Flood Risk Adaptation through Risk Based Insurance Premiums: Empirical Evidence from Germany." *Ecological Economics* 125: 1–13. 10.1016/j.ecolecon.2016.01.015.

[62] Insurance Council of New Zealand. 2013. "Submission on the Review of the Earthquake Commission Act." Tech. rep., ICNZ, Wellington. https://www.icnz.org.nz/. Argues that EQC should act as a first-loss insurer, with private insurers covering over-cap losses.

[63] Jaffee, Dwight M. and Thomas Russell. 2000. "Behavioral Models of Insurance: The Case of the California Earthquake Authority." Tech. rep., National Bureau of Economic Research. Paper prepared for the NBER Insurance Conference.

[64] Jerch, Rhiannon, Matthew E. Kahn, and Gary C. Lin. 2023. "Local Public Finance Dynamics

and Hurricane Shocks." *Journal of Urban Economics* 134: 103560. 10.1016/j.jue.2022.103560.

[65] Kahn, Matthew E. and V. Kerry Smith. 2017. "The Affordability Goal and Prices in the National Flood Insurance Program." NBER Working Paper 24120, National Bureau of Economic Research.

[66] Keys, Benjamin J. and Philip Mulder. 2024. "Property Insurance and Disaster Risk: New Evidence from Mortgage Escrow Data." Working Paper 32579, National Bureau of Economic Research. 10.3386/w32579.

[67] Kirchgässner, Gebhard. 2007. "On the Efficiency of a Public Insurance Monopoly: The Case of Housing Insurance in Switzerland." In *Public Economics and Public Choice: Contributions in Honor of Charles B. Blankart*, edited by Pio Baake and Rainald Borck, pp. 221–242. Berlin: Springer. 10.1007/978-3-540-72782-8_13.

[68] Klosin, Sylvia and Adam Solomon. 2024. "Optimal Insurance Scope: Theory and Evidence from US Crop Insurance." *Manuscript in preparation* .

[69] Kousky, Carolyn. 2018. "The Emerging Private Residential Flood Insurance Market in the United States." Tech. rep., Wharton Risk Management and Decision Processes Center, Philadelphia. https://esg.wharton.upenn.edu/wp-content/uploads/2023/07/Emerging-Flood-Insurance-Market-Report.pdf. Wharton Risk Center Report.

[70] Kousky, Carolyn and Howard Kunreuther. 2014. "Addressing Affordability in the National Flood Insurance Program." *Journal of Extreme Events* 1 (1): 1450001. 10.1142/S2345737614500018.

[71] Kousky, Carolyn and Howard Kunreuther. 2017. "Increased Cost of Compliance: Evaluation and Policy Options." Tech. rep., Wharton Risk Management and Decision Processes Center.

[72] Kousky, Carolyn, Erwann O. Michel-Kerjan, and Paul A. Raschky. 2018. "Does Federal Disaster Assistance Crowd Out Flood Insurance?" *Journal of Environmental Economics and Management* 87: 150–164. 10.1016/j.jeem.2017.05.010.

[73] Kousky, Carolyn, Michael Palim, Jiafen Pan, and Bin Zhu. 2020. "Flood Damage and Mortgage Credit Risk: Evidence from Hurricane Harvey." *Fannie Mae Working Paper* Fannie Mae Economics and Strategic Research Working Paper.

[74] Kroll Bond Rating Agency. 2024. "KBRA Affirms the Florida Hurricane Catastrophe Fund Finance Corporation Revenue Bonds." https://www.kbra.com. Press release describing assessment-backed security structure and ratings.

[75] Manning, Willard G., Joseph P. Newhouse, Naihua Duan, Emmett B. Keeler, Arleen Leibowitz, and M. Susan Marquis. 1987. "Health Insurance and the Demand for Medical Care: Evidence from a Randomized Experiment." *American Economic Review* 77 (3): 251–277.

[76] Marcoux, Kendra and Katherine R. H. Wagner. 2024. "Fifty Years of U.S. Natural Disaster Insurance Policy." In *Handbook of Insurance*, edited by Georges Dionne. Springer. Forthcoming chapter, CESifo Working Paper No. 10431.

[77] Marshall, David. 2018. "An Overview of the California Earthquake Authority." *Risk Management and Insurance Review* 21 (1): 51–73.

[78] McAneney, John, Delphine McAneney, Rade Musulin, George Walker, and Ryan Crompton. 2016. "Government-sponsored natural disaster insurance pools: A view from down-under."

International Journal of Disaster Risk Reduction 15: 1–9. 10.1016/j.ijdrr.2015.11.004.

[79] Medicare Payment Advisory Commission. 2024. "March 2024 Report to the Congress: Medicare Payment Policy." Tech. rep., Medicare Payment Advisory Commission, Washington, DC. https://www.medpac.gov/wp-content/uploads/2024/03/March_2024_MedPAC_Report_Press_Release_SEC.pdf. Press Release. Embargoed until March 15, 2024. Contact: Stephanie Cameron, scameron@medpac.gov, (202) 220-3700.

[80] Michel-Kerjan, Erwann O. 2010. "Catastrophe Economics: The National Flood Insurance Program." *Journal of Economic Perspectives* 24 (4): 165–186. 10.1257/jep.24.4.165.

[81] Ministry of Finance Japan. 2024. "Outline of the Earthquake Insurance System in Japan." https://www.mof.go.jp. Includes premium discounts for earthquake-resistant buildings.

[82] Möhr, Christoph, Jeffery Yong, and Manuela Zweimueller. 2025. "Mind the Climate-related Protection Gap: Reinsurance Pricing and Underwriting Considerations." Fsi insights on policy implementation no. 65, Bank for International Settlements, Financial Stability Institute. https://www.bis.org/fsi/publ/insights65.pdf.

[83] Mulder, Philip. 2024. "Mismeasuring Risk: The Welfare Effects of Flood Risk Information." *SSRN Electronic Journal* 10.2139/ssrn.4966795. Available at SSRN: https://ssrn.com/abstract=4966795, doi:10.2139/ssrn.4966795.

[84] National Association of Realtors. 2025. "NAR Calls for Regulatory Reforms to Expand Private Flood Insurance Market." NAR Washington Report. https://www.nar.realtor/washington-report/nar-calls-for-regulatory-reforms-to-expand-private-flood-insurance-market.

[85] National Institute of Building Sciences. 2019. "Natural Hazard Mitigation Saves: 2019 Report." Tech. rep., NIBS.

[86] National Research Council. 2015. *Affordability of National Flood Insurance Program Premiums: Report 1*. Washington, DC: National Academies Press.

[87] Neptune Flood. 2025. "Transitioning NFIP Policies to the Private Market: A Path to a More Efficient Flood Insurance Landscape." Tech. rep. https://neptuneflood.com/research/transitioning-nfip-policies-to-the-private-market-a-path-to-a-more-efficient-flood-insurance-landscape/.

[88] New Zealand Treasury. 2021. "Regulatory Impact Statement: EQC Cap Increase." Tech. rep., New Zealand Treasury, Wellington. https://www.treasury.govt.nz/sites/default/files/2021-10/eqc2-ris-4403991.pdf.

[89] Nguyen, Cuong Nhu and Ilan Noy. 2020. "Comparing Earthquake Insurance Programmes: How Would Japan and California Have Fared after the 2010–11 Earthquakes in New Zealand?" *Disasters* 44 (2): 367–389. 10.1111/disa.12371.

[90] Noy, Ilan and Aekkanush Nualsri. 2011. "Fiscal Storms: Public Spending and Revenues in the Aftermath of Natural Disasters." *Environment and Development Economics* 16 (1): 113–128. 10.1017/S1355770X10000446.

[91] OECD. 2021. "Enhancing Financial Protection Against Catastrophe Risks: The Role of Catastrophe Risk Insurance Programmes." Tech. rep., Organisation for Economic Co-operation and Development. https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/10/enhancing-financial-protection-

against-catastrophe-risks_094e2882/338ba23d-en.pdf.

[92] OECD. 2022. "Could Insurance Provide an Alternative to Fiscal Support in Crisis Response?" Tech. rep., Organisation for Economic Co-operation and Development, Paris. https://doi.org/10.1787/1d120193-en.

[93] OECD. 2023. "Enhancing the Insurance Sector's Contribution to Climate Adaptation." Tech. Rep. 26, OECD, Paris.

[94] OECD and World Bank. 2019. "Fiscal Resilience to Natural Disasters: Lessons from Country Experiences." Tech. rep., Organisation for Economic Co-operation and Development and World Bank.

[95] of U.S. Senator Adam Schiff, Office. 2025. "NEWS: Sen. Schiff Introduces Bill to Stabilize Insurance Market, Protect Homeowners from Increased Costs of Natural Disasters." Press Release. https://www.schiff.senate.gov/news/press-releases/news-sen-schiff-introduces-bill-to-stabilize-insurance-market-protect-homeowners-from-increased-costs-of-natural-disasters/. Accessed: December 9, 2025.

[96] O'Neill, John and Martin O'Neill. 2012. "Social Justice and the Future of Flood Insurance." Tech. rep., Joseph Rowntree Foundation, York, UK.

[97] Oxford Policy Management. 2024. "Independent Evaluation of the African Risk Capacity: Impact Assessment Phase 1 Final Report." Tech. rep., Oxford Policy Management. https://www.opml.co.uk/sites/default/files/2025-02/arc-ia1-evaluation-report.pdf. Commissioned by UK Foreign, Commonwealth and Development Office.

[98] Paragon Strategic Solutions, Inc. 2024. "Florida Hurricane Catastrophe Fund 2024 Ratemaking Formula Report." Tech. rep., State Board of Administration of Florida. Ratemaking report for the 2024–2025 contract year.

[99] Paudel, Youbaraj. 2012. "A Comparative Study of Public–Private Catastrophe Insurance Systems: Lessons from Current Practices." *The Geneva Papers on Risk and Insurance – Issues and Practice* 37 (2): 257–285. 10.1057/gpp.2012.10.

[100] Pauly, Mark V. 1968. "The Economics of Moral Hazard: Comment." *American Economic Review* 58 (3): 531–537.

[101] Poussin, Julie K., W. J. Wouter Botzen, and Jeroen C. J. H. Aerts. 2013. "Stimulating Flood Damage Mitigation through Insurance: An Assessment of the French CatNat System." *Environmental Hazards* 12 (3-4): 258–277. 10.1080/17477891.2013.832650.

[102] Rapoport, Andrew J. and Paragon Strategic Solutions Inc. 2025. "2025 Ratemaking Formula Report." Tech. rep., Florida Hurricane Catastrophe Fund, Minneapolis, MN. https://fhcf.sbafla.com/media/unyktojp/2025-ratemaking-formula-report.pdf. Presented to the State Board of Administration of Florida, March 26, 2025.

[103] Raschky, Paul A. and Manijeh Schwindt. 2016. "Aid, Catastrophes and the Samaritan's Dilemma." *Economica* 83 (332): 624–645. 10.1111/ecca.12194.

[104] Raymond James & Associates. 2025. "Florida Hurricane Catastrophe Fund Annual Report of Aggregate Net Probable Maximum Losses, Financing Options, and Potential Assessments February 2025." Tech. rep., Florida Hurricane Catastrophe Fund. https://fhcf.sbafla.com/media/elzjfd3m/fhcf-2025-pml-report.pdf.

[105] Sastry, Parinitha, Ishita Sen, and Ana-Maria Tenekedjieva. 2024. "When Insurers Exit: Climate

Losses, Fragile Insurers, and Mortgage Markets." Working Paper 4674279. 10.2139/ssrn.4674279. Available at SSRN.

[106] Sengupta, Rohini and Carolyn Kousky. 2020. "Parametric Insurance for Disasters." Wharton Risk Center Primer. https://impact.wharton.upenn.edu/wp-content/uploads/2023/07/Parametric-Insurance-for-Disasters_Sep-2020.pdf.

[107] Shi, Song and Michael Naylor. 2023. "Perceived Earthquake Risk in Housing Purchases." *Journal of Housing and the Built Environment* 38: 1761–1787. 10.1007/s10901-023-10012-6.

[108] Simmons, Kevin M., Jeffrey Czajkowski, and James M. Done. 2018. "Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida." *Land Economics* 94 (2): 155–174. 10.3368/le.94.2.155.

[109] Solomon, Adam. 2025. "When Insurance Markets Fail: Catastrophe-Risk Frictions and Public Reinsurance." Working paper, New York University Stern School of Business. Current version: November 2025.

[110] State of Florida. 2025. "Florida Statutes, Title XIV, §215.555: Florida Hurricane Catastrophe Fund." https://www.leg.state.fl.us/statutes/. Includes requirement that reimbursement premiums be actuarially indicated.

[111] Surminski, Swenja. 2018. "Fit for Purpose and Fit for the Future? An Evaluation of the UK's New Flood Reinsurance Pool." *Risk Management and Insurance Review* 21 (1): 33–72. 10.1111/rmir.12093.

[112] Surminski, Swenja et al. 2019. "Insurance as a Catalyst for Government Climate Planning? A Working Paper on the Role of Insurance in Climate Risk Governance." Tech. rep., Grantham Research Institute on Climate Change and the Environment, London School of Economics.

[113] Swiss Reinsurance Company Ltd. 2012. "The Essential Guide to Reinsurance." Tech. rep., Swiss Re, Zurich. https://www.swissre.com/dam/jcr:d06472ab-2625-48cf-8b4e-7c7ac8aa63f0/The-essential-guide-to-reinsurance.pdf.

[114] Syphard, Alexandra D., Teresa J. Brennan, and Jon E. Keeley. 2014. "The Role of Defensible Space for Residential Structure Protection During Wildfires." *International Journal of Wildland Fire* 23 (8): 1165–1175. 10.1071/WF13158.

[115] Thomson, Hope, Harrison B. Zeff, Rachel Kleiman, Antonia Sebastian, and Gregory W. Characklis. 2023. "Systemic Financial Risk Arising from Residential Flood Losses." *Earth's Future* 11 (1): e2022EF003206. 10.1029/2022EF003206.

[116] Tilloy, A., B. D. Malamud, H. Winter, and A. Joly-Laugel. 2019. "A review of quantification methodologies for multi-hazard interrelationships." *Earth-Science Reviews* 196: 102881. 10.1016/j.earscirev.2019.05.019.

[117] UNFCCC Secretariat. 2023. "Financial Arrangements for Addressing Loss and Damage: Primer on Loss and Damage Finance." Tech. rep., United Nations Framework Convention on Climate Change, Bonn. https://unfccc.int/documents/631091. Discusses the use of parametric insurance for governments, tourism and environmental sectors, including coverage of non-economic and budgetary impacts beyond direct physical damage.

[118] United States Government Accountability Office. 2007. "National Flood Insurance Program: Greater Transparency and Oversight of Wind and Flood Damage Determinations Are Needed." Tech. Rep. GAO-08-28, United States Government Accountability Office. https://www.gao.

gov/assets/gao-08-28.pdf.

[119] U.S. Government Accountability Office. 2009. "Flood Insurance: Opportunities Exist to Improve Oversight of the Write-Your-Own Program." Tech. Rep. GAO-09-455, Government Accountability Office, Washington, DC. https://www.gao.gov/products/gao-09-455.

[120] U.S. Government Accountability Office. 2017. "Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience." Tech. Rep. GAO-17-425, GAO, Washington, DC.

[121] U.S. House of Representatives. 1995. "H.R. 1856: Natural Disaster Protection Partnership Act of 1995." https://www.congress.gov/bill/104th-congress/house-bill/1856. Introduced in House June 15, 1995.

[122] Wang, Haoluan. 2021. "Flood Your Neighbors: Spillover Effects of Levee Building." Working paper, University of Maryland.

[123] Williams, Rebecca, Lorilee A. Medders, Michael Nevius, and Martin Sinder. 2023. "Flood Insurance Redesigned: Regulatory Considerations for a Viable and Sustainable Private Market." *Journal of Insurance Regulation* 42 (1): 1–45.