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Review article

Government-sponsored natural disaster insurance pools: A view from down-under

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ABSTRACT

In the light of the rising cost of natural disasters we review the provision of catastrophe insurance by the public sector in the US, France, New Zealand, Spain, the United Kingdom, and its absence in the Netherlands, where flood risk is viewed as a national security concern. We do this in the context of the Australian home insurance market where insurers increasingly employ risk-reflective, multi-peril premiums as new technology allows them to better understand their exposure to risk. Motivations behind government pools vary by country, as do hazard profiles. In the US, for example, pools have usually arisen in the face of market failure of private sector insurance following a significant natural disaster; the initial concern has been the provision of affordable insurance rather than disaster risk reduction. Government pools have certain advantages over the private sector including their ability to raise funds post-event, but face financial unsustainability given political intervention to maintain affordability of cover in high-risk areas. In Australia, it is too early to judge whether risk-based premiums are leading to better land-use planning and increased mitigation spending, but in the case of northern Australia, a region that faces flooding and tropical cyclone risks, rising premiums are causing concern in Government. Nonetheless, the corollary seems self-evident, i.e. in the absence of transparency about the cost of risk, there is no incentive on the part of homeowners, local councils or land developers to improve the 'riskscape'; insurers are the only actors with immediate financial incentives to acknowledge these risks.
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Contents

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1. Introduction

Dealing with the threat of natural perils in ways that increase the resilience of communities poses a difficult policy area for government. Australia, like other jurisdictions, is episodically impacted by natural disasters from a wide range of perils [15]; in fact six different peril categories are responsible for the top 10 normalised insurance losses (Table 1). Much of the damage in such events is self-inflicted in the sense that the outcomes are heavily modulated by where and how we choose to live. If we take the case of flood, for example, on Wednesday, 5 March 1819, in the fledgling years of the Australian colony, the then Governor of New South Wales, Lachlan Macquarie, felt moved to issue a Government and General Order to be read in every church and chapel in Australia for the three ensuing Sundays. This followed large floods in the Hawkesbury River catchment near Sydney, a river system that continues to pose a significant threat to much larger populations today. The Governor criticised new settlers [for if it had not been for their]:

wilful and wayward Habit of placing their Residences and Stockyards within the Reach of the Flood (as if putting at Defiance that impetuous element which it is not for Man to contend with), many of the deplorable losses which have been sustained within the last few years at least, might have been in great Measure averted [13].

Essentially there are two primary ways of reducing the direct economic costs of catastrophic events: either by way of mitigation[1] measures, or by reducing the financial impact on those directly affected with the sharing of costs among a wider population through government and/or charitable aid, or insurance. Government aid comes often in the form of post-event appropriations that can create budgetary difficulties and disincentives for mitigation [8,34,60,59]. This being the case, most advanced economies rely on insurance to fund a significant portion of disaster recovery and to diversify this risk through international reinsurance markets. Reinsurance, the insurance of insurance companies, has the added benefit of providing financial resources external to the local economy; this has been an important factor in the reconstruction of Christchurch following the destruction due to the 2010-2011 earthquake sequence, an event to which we will return in our discussion of New Zealand's Earthquake Commission (EQC).

Our study was motivated by questions about the role of government in the provision of catastrophe insurance and the potential for the insurance sector to be a positive actor in reducing the economic costs of natural disasters [50]. Both questions had high currency in Australia after the 2011 Queensland and Victorian floods, events that led to widespread public and political criticism of many insurers for their then failure to cover riverine flood damage [70]. Australian insurers have since responded by broadening coverage, so that as of May 2015 over 90% of homeowner's policies cover this peril [59]. This change has been possible largely because of the increased disclosure of flood mapping commissioned by local councils and the processing of these data in ways to allow for better risk identification [47,33,59].

The Australian experience in respect of flood insurance is just one manifestation of how advances in the use of Geographic Information Systems, remote sensing and simulation modelling are changing insurers' ability to understand and price their exposure to risk [52,74,75,29,55]. As a result of improving intelligence, private sector insurers may choose to offer cover only at rates far in excess of what those consumers were paying in the past, or even to withdraw from areas deemed too high risk [7]. At the time of writing this is an issue in northern Australia, a region prone to tropical cyclones and episodic flooding, and where premiums have risen to better reflect these risks [5]; the government has responded to public concern by convening a taskforce (The Northern Australia Insurance Premiums Taskforce: http://jaf.ministers.treasury.gov.au/media-release/024-2015/) to explore how premiums can be reduced; one of the mechanisms under consideration is a government-sponsored tropical cyclone reinsurance pool, like those evaluated in this study.

With this in mind we scrutinise various government-sponsored natural disaster insurance pools (sometimes called *residual market mechanisms* and hereafter *Government pools* or *pools*) in the US, New Zealand, Spain and France, as well as arrangements under consideration in the UK and their absence in The Netherlands. In ignoring pools in Japan, Scandinavia, Switzerland, Taiwan and Turkey, amongst others (see [46]), our survey makes no claim to be exhaustive. However it samples from the spectrum of possible arrangements and highlights certain challenges that beset all of them in dealing with the rising cost of natural disasters [63]. Following a brief overview of the various pools examined, subsequent discussion centres upon three questions: How do the pools price risk? How are deficits funded? Do the pools encourage disaster risk reduction? We then draw upon some illustrative examples from recent Australian experience of the role played by poor land-use planning in amplifying the cost of natural disasters and conclude with some discussion on the capacity of the insurance industry to help overcome this problem.

Lastly by way of introduction, *risk* in this paper refers to the financial risk defined as a multivariate function of: *hazard attributes* – for example, the frequency of landfalling tropical cyclones with peak gust speeds in excess of thresholds likely to cause property damage; *exposure* – the spatial distribution of insured assets and their values; and *vulnerability* – the cost of damage as a fraction of the insured or replacement value for a given hazard intensity. This conceptual framework underpins all catastrophe loss modelling that is now standard practice in the insurance industry to help inform its purchase of reinsurance, capital needs and increasingly, premium pricing [72]. In other contexts, risk has behavioural dimensions [62] but these are not considered here.

2. Brief overview of selected Government-sponsored disaster insurance pools

2.1. US pools

Since US pools have attracted significant scholarship (e.g.

Table 1
Top 10 Australian normalised (2014–2015) insurance sector natural disaster loss events. Normalised losses refer to the estimated insurance cost of historical hazard events if they were inflicted upon current society. The normalisation adjusts original losses for changes in building numbers; the average nominal value of new buildings since the time of the original event; and for the increased resilience of newer buildings in tropical cyclone-prone parts of the country (updated from [15]).

Rank	Year	Event	Cost (Millions AUD)
1	1999	Sydney Hailstorm	4475
2	1974	Tropical Cyclone Tracy	4178
3	1989	Newcastle Earthquake	3834
4	1974	Brisbane Floods	2701
5	2011	Queensland and Victorian Floods	2506
6	1983	Ash Wednesday Bushfires (Wildfires)	2371
7	1985	Brisbane Hailstorm	2046
8	2007	Pasha Bulker East Coast Low Storm	1966
9	1973	Tropical Cyclone Madge	1520
10	1990	Sydney Hailstorm	1433

[1] Here we refer to *mitigation* in its traditional sense of precautionary risk-reduction measures rather than reducing greenhouse gas emissions as in the parlance of climate change.

[9,34,35,39,42–45]), the following introductory sketches are kept short. To the degree that their attributes and management shed light on the particular questions of interest to our study, we describe these in more detail in Sections 3 through 5.

With the exception of nationwide flood cover provided by the ***National Flood Insurance Program*** **(NFIP)**, it is the individual State (c.f. Federal responsibility) that controls its own catastrophe insurance market. NFIP, administered by the Federal Emergency Management Agency (FEMA), was created in 1968 following the withdrawal of private insurers after large losses incurred during Hurricane Betsy (1965). An important feature of NFIP is that flood cover not only encompasses riverine flood damage but also that caused by hurricane-induced storm surge. It is the latter peril that, in large measure, has been responsible for NFIP's current large deficit (see later discussion).

*The Texas Catastrophe Property Insurance Associatio*n was established as a government pool offering last resort windstorm and hail insurance in 1971 following large losses in Hurricane Celia (1970). In 1997, the program was renamed the ***Texas Windstorm Insurance Association*** **(TWIA)**. All Texas property and casualty insurers are required to participate and represent eligible property owners in the 14 coastal counties along the Gulf Coast and parts of Harris County. Losses in excess of revenue are paid by the ***Catastrophe Reserve Trust Fund*** **(CRTF)**, which was established in 1993 to manage TWIA's revenue and liability, reinsurance and public securities.

Florida suffered a crisis in the availability of property insurance in the late 1960s at a time when residential property mortgage finance was conditional on insurance cover and many homeowners were threatened with mortgage default. In response the State Legislature mandated in 1970 that insurers participate in the *Florida Windstorm Underwriting Association* (FWUA) programme to provide *affordable* (not risk-rated) homeowner cover for catastrophic windstorm events in *high-risk areas* along the Florida coastline. (The conflict between *affordability* and *high-risk* emerges as an issue faced by many of the pools examined in this study.) To increase capacity, the FWUA merged in 2001 with the *Joint Underwriting Association* (JUA), a temporary programme established by the Legislature to provide short-term cover to policyholders planning repairs for damage incurred during Hurricane Andrew (1992), and from this merger ***Citizens***, an entity with tax-exempt status and securities, was created [14].

Citizens is funded by premiums, regular assessments[2] on insurers, government and agency securities, corporate bonds, municipal bonds and private sector securities. Shortfalls are covered by policyholder surcharges, emergency assessments and bond issues. Insurers of private property are also required to participate in the ***Florida Hurricane Catastrophe Fund*** **(FHCF)**, which was established in 1993 to provide low-cost reinsurance cover for future hurricane losses [24]. This has the effect of further concentrating Florida's hurricane risk within the state rather than diversifying it around the world. The FHCF has recently begun to purchase some external risk transfer products such as reinsurance; nonetheless, in the foreseeable future the FHCF will hold a large proportion of its claims paying capacity in the state from accumulated cash and bonding.

In contrast to mortgage lender requirements for windstorm cover in Florida (and for flood nationally for Federally-backed home loan mortgages), earthquake insurance in California has not been a requirement for mortgage finance. Despite the fact that since 1985 residential insurers had been required to offer earthquake cover to all prospective policyholders, only a third of homeowners in the area impacted by the Northridge earthquake (1994) had purchased cover at the time. Insurers were liable for claims of $15 billion despite having received a mere $3.4 billion in premiums over the previous 25 years [39]. To ensure ongoing availability of earthquake cover, the ***California Earthquake Authority*** **(CEA)** was established in 1996 as a tax-exempt, not-for-profit, largely privately-funded pool to cover seismic damage in that State. Insurers had the option of paying an “exit tax” and offering cover, or transferring funds and participating in the pool; 70% agreed to transfer funds, which together with premiums and return on investments provides the total CEA income. It has no recourse to government backup [11]. California continues to have low uptake of earthquake insurance, however, with 88% of homeowners adopting to be self-insured against this threat [10]. High deductibles (10% or 15% of the sum insured) and premiums may be a contributing factor for this low take-up [45].

2.2. Examples of non-US pools

Also prone to earthquakes, New Zealand has adopted a different approach from the CEA to insuring the risk of earthquakes and other natural perils. The ***Earthquake Commission*** **(EQC)** provides automatic first loss cover for valid claims for all policyholders of residential fire insurance. Hazards covered comprise earthquake, natural landslip, tsunami, volcanic eruption, hydrothermal activity, restricted storm or flood damage to residential land, and fire following any of the afore-mentioned events. Premiums are collected through a compulsory levy added to all homeowner policies, and private insurers transfer the levy to the EQC for investment by the ***Natural Disaster Fund***. Owners of non-insured property can expect no help from government.

The maximum cover from EQC is currently NZ$100,000 (plus Goods and Services Tax (GST)) for home and NZ$20,000 (plus GST) for home contents and comes at a cost of 15c per $100 of insurance cover (excluding GST) per annum for damage arising from *each* natural disaster event, *regardless of risk* [19]. Until the premium cost was tripled from 5c in 2012, it had been unchanged per dollar of cover since the scheme's inception in 1945 [65]. EQC has been ‘sorely tested' by the 2010–2011 Christchurch earthquakes[3] with peak ground accelerations in the CBD close to the 500-year Average Recurrence Interval (ARI) building code design level for the September 4, 2010 (Darfield) event, and twice those design levels for the February 22, 2011 event [3]. Many of EQC's provisions and operations are now under review [65].

In 1941, following the Spanish Civil War, the ***Consorcio de Compensación de Seguros*** **(CCS)** was founded to indemnify Spanish insurance companies against claims arising from unpredictable events including natural disasters. It became a permanent state-run, private-public partnership in 1954 providing nationwide, state-guaranteed cover for extraordinary risks [6]. Extraordinary events cover is a compulsory component of all insurance policies for life, fire and natural perils, motor vehicle damage, property damage and personal accidents. Private insurers may offer this cover themselves, but most opt out adding the CCS surcharge to premiums and transferring the surcharge less a 5%

[2] Assessments are charges made to private insurers participating in government pools either on a regular basis (regular assessments) to cover operating costs or after an event should losses exceed the capacity of the program to settle claims (emergency assessments).

[3] On September 4, 2010, the first of a swarm of earthquakes impacted Christchurch, the largest city in the South Island of New Zealand; it was a Moment Magnitude 7.1 earthquake with its epicentre at Darfield, 40 km west of the city. The third of five quakes designated as ‘insurance' events occurred on February 22, 2011, centred 5 km southeast of Christchurch; this Moment Magnitude 6.3 event resulted in seismic motions well in excess of those underpinning the building code. 185 people died and damage to the CBD was such that much of it has now been demolished and large areas of former residential property designated unsuitable for rebuilding due to liquefaction. The cost of recovery is estimated at some $NZ40 billion or 20% of annual Gross National Product (GNP) [66; 21].

deduction to cover transaction expenses [48,53]. The costliest year for losses was 1983, when flooding in the Basque Country, Cantabria and Navarra caused insured losses amounting to €623 million [57,6].

The inclusion of natural catastrophe insurance cover in France is also mandatory in all comprehensive home insurance policies. Created in 1982, the French ***Caisse Centrale de Réassurance*** **(CCR)** is a public-private partnership providing government-guaranteed reinsurance. As part of the French Cat. Nat. scheme CCR was founded on the principle of national *solidarity,* leading to catastrophe insurance available to all at rates set by decree and uniformly priced *regardless of risk* [51]. Private insurers have the choice of reinsuring either with the state-owned CCR or the private market but contracting with the CCR is the preferred option. Insurers generally transfer 50% of their natural peril risks to CCR and pay that entity 50% of their natural disaster premiums in a quota-share-like arrangement [28].

In the UK, the Government and private sector insurers entered into an unwritten *Gentlemen's Agreement* that has led to private sector flood insurance operating in the UK since the early 1960s [32]. This agreement was that no residential property would be refused flood cover, except in areas where flooding was too frequent to be insurable, and on the understanding that the Government provide sufficient flood protection. It was an arrangement tested by widespread flooding in 1998 and 2000. A temporary arrangement called the *Statement of Principles*, incorporating the Gentlemen's Agreement was then forged, with the proviso that if Government did not improve flood defences and tighten regulations, insurers would withdraw their guarantee to cover all but exceptional risks [7].

The Statement of Principles was renewed and revised until its expiry drew near in 2013. After much discussion, an in-principle agreement was reached in June 2013 to replace the expiring agreement with a partnership to establish ***Flood Re*** as a not-for-profit fund owned and managed by the insurance industry. Flood Re will provide flood cover for an estimated 2% of properties, for whom obtaining flood cover is currently problematic, and do so at premiums that will be capped and subsidised by a levy on all other insured homeowners whose flood risk will continue to be priced by the market. This levy will pass to Flood Re, which will seek reinsurance cover from the global reinsurance market; losses from extreme flooding (with Annual Return Intervals (ARI) greater than 200 years), however, will be the responsibility of government [4]. The scheme is expected to be operational in 2016 and have a 25-year lifetime during which premiums are expected to move towards being fully risk-reflective [7].

With roughly 26% of its land area lying below mean sea level and another 29% prone to riverine flooding (Netherlands Environmental Protection Agency: http://www.pbl.nl/dossiers/klimaatverandering/content/correctie-formulering-over-overstromomgsrisico), the Netherlands faces an existential threat from flooding. Combatting this threat is taken as a government responsibility. In response to the 1953 disaster[4] when 1836 people lost their lives, 100,000 were people evacuated and 4500 buildings destroyed, the Government initiated the construction of the Delta Works. This comprises 53 dyke-ring areas, each a closed system consisting of dams, dykes, sluices and storm surge barriers that were completed in 1997. Legislation requires that the Delta Works provide protection to water levels equalling or exceeding an ARI of 10,000 years along the coast, and to 1250 years along the riverbanks. According to Aerts et al. [2], the system will need to be updated to adapt to rising sea levels and anticipated increases in precipitation.

3. Pricing of risk

In few of the government pools examined herein were premiums risk-reflective at the individual property level. The term risk-reflective or risk-based is to be distinguished from *actuarially sound*, an elusive term usually understood to mean that rate-making includes the expected value of all future obligations: claim settlement expenses, operational and administrative fees, reinsurance and the cost of capital [1]. Of course pools may be actuarially sound from a solvency perspective in the sense of having sufficient reserves and reinsurance arrangements to meet their statutory obligations but nonetheless still choose not to impose risk-reflective premiums upon policyholders. This expressly means that low-risk households are subsidising those more at risk. This is the case, for example, with the policies of CCS in Spain that are based on principles of *compensation, solidarity and cooperation* [53]. This is also true of CCR in France and EQC in New Zealand where homeowners are charged uniform rates regardless of their individual risk. Hallegate [30] argues that there are rational economic arguments for subsidising insurance in economically important regions, but to our knowledge this notion has not been expressly tested. The Treasury [65] discussion document of EQC post the Christchurch earthquakes argues for continuing use of non-risk reflective pricing on affordability grounds.

NFIP has been criticised for charging below actuarially sound rates because “the program does not collect sufficient premium to build reserves to meet the long-term future expected flood losses including catastrophe losses [and so] it is inevitable that losses from claims and the program's expenses will exceed the funds available … in some years and, cumulatively over time” [69]. The annual target for the program's overall premium is at least the amount of losses and expenses in an *average* historical year and does not consider the potential for more extreme losses (see next section). In other words, there is a high likelihood of events with costs in excess of the long-term average that cannot be covered out of the current year's premium. Moreover Congress has authorised subsidised insurance rates for policies covering certain structures to encourage communities to join the programme. Thus in the words of the 2001 report of the Government Accounting Office [69], the scheme is *actuarially unsound by design*. NFIP losses above its capital or reserve levels are funded by borrowing from the US Treasury and are intended to be repaid over time by policyholder premiums [1].

Historically, Citizen's premiums in Florida have not been risk-based. In 2009 legislation was passed requiring Citizens to move towards actuarially sound rates by following a “glide-path” of annual increases, but with increases capped at approximately 10% p.a. (“Actuarially sound” in this case means that premium income is sufficient to cover projected claims resulting from a 100-year ARI event for the coming season, without resorting to insurer or policyholder assessments). To decrease exposure, a depopulation program is in place.

More than 10 years has now passed since the last major hurricane made landfall in Florida (Hurricane Wilma in 2005) (http://rogerpielkejr.blogspot.com.au/2014/06/the-us-hurricane-drought-in-usa-today.html), the longest hurricane ‘drought' on record, and Citizens has reduced its exposure to less than 1 million policyholders. By 2014 premium rates had risen to a level that Citizens considered actuarially sound, and cash reserves of over $7.66 billion had been accumulated when aggregated across all lines of

[4] The 1953 disaster was caused by surge from a major storm that tracked across northwestern Europe. Coinciding with a spring tide, the surge caused record high water levels breaching 150 sea dykes and more inner dykes. Once breached, there was nothing to prevent the spread of water through low-lying areas [27]. The same event also caused 307 deaths in England and another 19 in Scotland and ultimately led to the construction of the Thames Barrier (http://www.metoffice.gov.uk/news/in-depth/1953-east-coast-flood).

business [64]). Some private insurers were authorised to lower rates, and Citizens was considering decreases in 2015. This experience illustrates the sensitivity of disaster insurance schemes to the temporal volatility of event losses, in this case a lower than normal sequence of losses, and the value of government guarantees when the reverse is true.

Some areas of Florida now pay actuarially sound rates, but much of the coastal and other high-risk areas remain significantly under-priced [36]. The state regulator in June of this year, however, approved changes for 2016 that include average rate decreases of 1% for inland (low-risk) multi-peril cover and average increases for coastal residential wind-only policyholders of 8.8% (http://www.sun-sentinel.com/business/consumer/fl-citizens-2016-pricing-20150622-story.html). Citizens suggests that it will then have the potential to fully cover losses to their portfolio from a 100-year ARI hurricane.

As for the CEA, its premiums are required by legislation to be based on modelled estimates of expected losses [35]. However initial premium settings met with political and consumer pressure and so CEA chose to rate at a reasonably coarse spatial resolution using only 19 rating zones for the state and also reduced the overall level of premiums especially in high risk areas. This has created opportunities for non-CEA insurers to offer reduced premiums in low risk areas.

TWIA employs catastrophe loss modelling to simulate event losses from landfalling hurricanes to its Book of Business but makes no premium differentiation in respect to geographic location. Properties certified as conforming to more stringent construction codes are, however, subject to premium discounts. TWIA pricing was discussed at the Meeting of the TWIA Underwriting and Actuarial Committee on 30th July, 2015 (https://dl.dropboxusercontent.com/u/53088391/Actuarial%20and%20Underwriting%20Meeting/TWIA-Actuarial%20and%20Underwriting%20Committee%20Meeting.mp3) and at the TWIA Board on 4th August 2015, (https://dl.dropboxusercontent.com/u/53088391/Board%20Meetings/TWIA-Galveston-2015-Tues.mp4). “Actuarial pricing” as adopted by TWIA is defined as premium rates that over the long-term match modelled losses. However there was some confusion about whether as implemented this would meet the pool's statutory obligations to be able to pay claims on a 100-year ARI event, if repeated in successive seasons. The group actuary acknowledged that TWIA would not have the funds to cover a second event but dismissed that circumstance as “unlikely.” This view completely ignores the likelihood of clustering of events between and within seasons favourable to the development of severe tropical cyclones.

4. Dealing with deficits

Government pools usually contain an inherent contradiction in trying to provide *low cost* insurance to *high-risk* properties and so the funding of deficits to which they are inevitably prone becomes important. The fat-tailed nature of catastrophe loss distributions also predisposes pools to deficits because of the possibility of losses very much larger than either previous loss experience [40,41] or the estimated 100-year ARI loss.[5] In what follows we examine the deficit history of the Government pools scrutinised here.

With financial backup of the state, government pools can fall back on resources not available to the private sector: Hurricane Katrina (2005) and Super Storm Sandy (2012), for example, rendered NFIP technically insolvent, but it was able to fall back on its Federal government guarantee to stay in business. Congress increased NFIP's borrowing authority from the US Treasury from a pre-Katrina level of $1.5 billion to $20.8 billion, and again in 2013 post-Sandy to $30.4 billion; its annual premium income is around $3.5 billion (2011) [38]. Policy holders are now very much dependent upon government largesse, a circumstance the scheme was presumably created to avoid.

When Hurricane Andrew made landfall in Florida in 1992, the private insurance industry was grossly undercapitalised due to increased exposure and competitive pricing; several insurers were subsequently rendered insolvent. The vehicle guaranteeing claims payments, the *Florida Insurance Guaranty Association*, with insufficient resources to cover the shortfall, was forced into a special bond issue resulting in assessments being passed to policyholders for many years [52]. The reinsurance vehicle, the Florida Hurricane Catastrophe Fund, also found itself in the same situation when its surplus was exhausted in the 2004 and 2005 seasons [24].

In the event of catastrophic losses turning its current surplus into deficit, Citizens would need to impose surcharges and emergency assessments on all property and casualty policies issued in Florida. According to the James Madison Institute [36], this would result in 78% of low-risk policyholders subsidising the losses of the remaining under-priced, high-risk properties. In the absence of a pool, private insurers would be required to charge rates sufficient to invest in risk transfer that would cover years of catastrophic loss.

In 2011 the Texas Department of Insurance placed the TWIA on Administrative Oversight whilst reforms were considered to improve its deteriorating financial position. In March 2013 the TWIA Board of Directors met to discuss their options for dealing with its 2012 deficit of $46,337,000 and considered declaring insolvency [67]. The Texas Department of Insurance subsequently amended the terms of Administrative Oversight citing operational improvements since 2011. Included in the reforms is a ‘depopulation' plan aimed to reduce its exposure by actively encouraging private insurers to assume TWIA policies [58].

In the case of CEA, which enjoys no government guarantee, if its losses were to exceed its capital reserves including reinsurance, then all policyholders would be required to pay a 20% premium surcharge to provide additional funds. Should these total resources still prove insufficient to pay claims, payments to policyholders would be prorated and only paid out in full when sufficient funds, such as from future premiums, became available [35].

Technical insolvency was also the fate of EQC after the 2010-11 Christchurch earthquakes wiped out its reinsurance cover and capital reserves that had accumulated since 1945 [20]. This was also the case for the CCR in France, whose government guarantee was required to recapitalise it after large losses due to flooding in the Aude area in November 1999 and windstorms Lothar and Martin in December of that same year [51]. In 2000, premium rates were increased by around 40% and reinsurance cover was limited to 50% [37].

In contrast to the other schemes surveyed here, the CCS in Spain has a large and growing surplus and its Government guarantee has not been called upon. This may be for a number of reasons: its broad subsidising base; catastrophe insurance being over-priced; or it may just reflect a gentle hazard history to date. We remind readers that this was also true of EQC in New Zealand until the Christchurch earthquakes.

The question of government-funded deficits has not arisen in the UK where the flood risk has to date been covered by the private sector, or in The Netherlands where the government manages flood risk through significant investments in engineering works.

[5] Note that this average loss based on recorded loss history differs from the Annual Average Loss as calculated in catastrophe loss models, which is typically estimated as the arithmetic average of a catalogue of simulated, but physically realisable, event losses, over a 50,000-year time series.

5. Encouraging mitigation

Government pools (and private insurers) can in principle minimise losses over time by encouraging risk mitigation, but, with two significant exceptions, we found limited evidence for this. Of the government pools considered, NFIP and TWIA are exceptions. Flood insurance in the US is mandatory for homes in high-risk flood areas with mortgage loans from federally regulated or insured lenders. FEMA produces maps identifying flood-prone areas; homeowners located in these areas can be eligible for discounted insurance rates if the community participates in an incentive program, the Community Rating System, and if local government commits to prescribed mitigation and flood management standards [22]. NFIP covers around 5.5 million properties out of which 20% receive discounted rates [25]. Thus a positive outcome of NFIP is the high percentage of local authorities imposing flood plain management schemes based on the 100-year ARI flood height;[6] however, Burby [9] questions the extent to which this has inhibited construction activity in flood-hazard areas or had much impact on federal disaster relief costs. Claims from hurricane-induced storm surge, on the other hand, pose a significant ongoing problem for NFIP and it is unclear how the organisation is addressing this.

In Texas, the TWIA has had a big influence on building standards, particularly for houses and other low-rise buildings. The program has been successful in enforcing mitigation measures by requiring buildings meet appropriate weatherproofing specifications of the WPI-8 certification. A Texas Department of Insurance (TDI) windstorm inspector checks buildings to ensure compliance with TWIA building specifications and, if the standards are met, a certificate is issued [68]. Prospective buyers now have an expectation of TDI Certification when viewing any property.

In California, CEA invests in mitigation measures including incentives for those in its programme to retrofit residential buildings but the low uptake of CEA cover limits its ability to materially reduce future losses.

While EQC in NZ has no direct responsibility for mitigation, it has played an important role in supporting research and development related to earthquake mitigation and promoting continuing improvements in building codes and planning regulations. Its national GeoNET programme of strong ground motion sensors has played an important role in understanding the character of the Christchurch earthquake ground motions and resulting damage to buildings and infrastructure. The New Zealand government also acted after these earthquakes by red-lining certain areas from redevelopment and purchasing properties within these zones, thereby reducing the risk in future earthquakes. These zones were mostly residential areas that had suffered widespread liquefaction. Again, however because premiums are not risk-reflective, EQC provides no incentive for the upgrading of older homes. This is also true of CCR in France, which sets rates by decree and uniformly *regardless of risk* [51].

In Spain, the CCS policy of charging uniform fees does not encourage risk-reducing measures on the part of policyholders. A directive initiated in 2007 to assess flood risk, produce flood risk maps and subsequent management plans is ongoing [23]. Historically the response to flooding in Spain has been to seek engineering solutions, but the collapse of the Tous dam in the region of Valencia in 1982, with the loss of life of at least 20 persons and many more having to be evacuated, has led to the realisation that flood control measures may encourage development on the floodplain, and the focus has been redirected towards more appropriate land-use planning and improvements in preparedness [61].

The proposed Flood Re programme in the UK is being designed with explicit responsibilities on government for mitigation. Under the new arrangements the government will also be liable for damage costs due to floods with ARIs in excess of 200 years. In practice the definition of what constitutes a 1-in-200 year event or event loss will be critically important.

As discussed earlier, the government of The Netherlands explicitly undertakes mitigation on behalf of the nation.

6. Discussion

In general it is US pools that have received the most academic scrutiny with the catalyst for their creation usually a large event loss that has seen the insurance sector faced with liabilities far in excess of its resources. Threatened with insolvency, companies voiced their intention to withdraw from the market and faced with what was seen as 'market failure', governments felt obliged to intervene in the market in order to sustain insurance availability. Thus the initial motivation behind the US pools has been the provision of catastrophe insurance cover, and not risk-reduction per se and there has been a tendency to keep premiums low across the board and to have policyholders in low-risk areas cross-subsidising those at higher risk [18]. In contrast, private insurers operating in a competitive market are increasingly obliged by market forces to set prices based on the risk to the policyholder. This is certainly the case in Australia.

Despite intentions to be the insurer of *last* resort, at least in the US, political intervention in setting premiums too low has sometimes seen government pools competing with the private sector and becoming the insurer of *first* resort. For example in 2008 after Hurricane Ike depleted the reserves of the TWIA, legislation was introduced in the following year requiring TWIA to stop pricing competitively and limit eligibility to property owners who had been declined insurance equivalent to basic TWIA cover by at least one private insurer [56]. Premium pricing continued to be actuarially unsound, however, with the undercapitalisation leaving the entity vulnerable to unmanageable losses.

While it is easy to make the case that insurance premiums should reflect actual risk, attempts to implement such practice are inevitably politically difficult. We have already referred to concern about rising premiums in northern Australia arising from a better appreciation by insurers of the tropical cyclone risk to certain classes of buildings. In the US, this tension has played out more dramatically where NFIP's deficit ultimately led to the introduction of the Biggert-Waters Flood Insurance Reform Act of July 2012. The reforms stipulated that rates should reflect current risk and this meant that rates would have risen tenfold in some cases. They were also to phase out discounted rates for 'grandfathered' properties and other repetitive-loss buildings[7]. In 2014, political reaction to the reforms led to the Homeowner Flood Insurance Affordability Act reversing many of Biggert-Waters' amendments, an

[6] We note in passing that the oft-used 100-year ARI flood height employed for NFIP and in Australia in land-use planning is a flawed risk metric, in Australia, at least. According to the National Flood Information Database [47], the difference in above-ground flood depths between the 100-year ARI and the notional Probable Maximum Flood vary from only a few tens of centimetres to nine metres across different catchments (Dr Keping Chen, Risk Frontiers, pers. com.) Clearly the risk to property will be very different across these.

[7] Grandfathered properties are those built before introduction of the FEMA guidelines and can neither be denied insurance by NFIP nor charged rates that reflect any reassessment of their flood risk. Historically such properties had been responsible for much of the insured losses with the Government Accountability Office [26]) finding that repetitive-claim properties, which comprised only some 1% of polices, were responsible for between 25% and 30% of claims. These figures represent the situation prior to the landfall of Super Storm Sandy in 2011.

act which will do little to alleviate the $24 billion debt NFIP still has to repay for losses incurred during Hurricane Katrina and Super Storm Sandy.

In the UK, the decision to create a new entity Flood Re, to which will be ceded most of the serious flood risk, took place after long discussions between government, the Association of British Insurers and other industry sector participants [31,7]. The UK is thus in a period of transition and aims to move towards risk-reflective private sector pricing over a 25-year period with the government accepting the 'tail risk' (event losses with an ARI greater than 200-years) and responsibility for mitigation. A key attribute of the design of the scheme that may ultimately prove decisive in reducing risk in the long term is the intention that Flood Re not be available for homes constructed after January 1, 2009 [7]. The implication is that homes constructed beyond this date will either be constructed outside of floodplains, or in flood resilient ways if they must be. Over time and provided this measure is enforced, the proportion of high-risk properties should decrease as they are 'diluted' by the increasing numbers of new homes built to better standards in respect of flood. This brings us to the issue of land use planning, which we discuss next.

7. Role of insurance in incentivising resilience: Australian examples

When we consider ways to address the increasing trend in disaster losses worldwide it is impossible to overlook the role played by poor land use planning. While this is an issue in most countries, we note here two examples from Australia: the 2009 Victorian bushfires (wildfires) and the 2010/11 Queensland and Victorian floods. In the former, studies undertaken for the 2009 Royal Commission [12,16,17] showed that 25% of destroyed homes were situated within 1m of the bush – effectively within the flame zone and part of the fuel load. Many people died in futile attempts to defend such properties.

Similar observations pertain to the 2011 flooding of Brisbane in an event leading to economic losses of some AU$6 billion and the introduction of a temporary reconstruction tax on the nation. Lost in the ensuing political debate was just how similar the flooding footprint in Brisbane was to that of the 1974 floods, and no doubt those of bigger floods in the 1800s [70]. In 2011 the flooded area was much more heavily developed than had been the case in 1974, with the Brisbane City Council approving between 2005 and 2011 1811 additional development applications in the area subsequently flooded (K. Doss, City Planning & Economic Development, pers. comm.).

It is too soon to judge whether the introduction of risk-reflective premiums is informing land use planning decisions in Australia, but insurers can exert market pressure in other ways. An example in 2012 was the temporary withdrawal of the Suncorp Group, one of the largest general insurers in Australia, from offering and renewing policies in the Queensland towns of Roma and Emerald. The 16-month withdrawal came after Suncorp announced it had paid out AU$150 million in claims and received AU $4 million in premiums after these towns flooded three times in two years (http://insurancenews.com.au/local/suncorp-quits-flood-towns-and-calls-for-mitigation-action). This outcome was only possible because of Suncorp's high market share in the region, high local awareness of the threat and the fact that prior to the Brisbane floods it was the only significant company offering flood insurance. Its withdrawal meant that policyholders who had been previously covered were no longer going to be. The decision brought about a rapid response on the part of government and the construction of levees.

The Productivity Commission [59] provides other Australian examples where premiums have been reduced following the construction of levees. It also notes discounted premiums in tropical cyclone-prone parts of the country for newer construction, which reflect their reduced likelihood of structural failure in high winds; McAneney et al. [49] estimate that the introduction of more wind-resilient construction standards post~1980 has reduced insurance losses in tropical cyclones by some 67%. Despite this, and as mentioned already, there is a perception that premiums in Northern Australia are excessive and the government is concerned that this could lead to significant levels of under- and self-insurance (The Northern Australia Insurance Premiums Taskforce: http://jaf.ministers.treasury.gov.au/media-release/024-2015/).

8. Implications for policy

Returning to the central question of this paper, as disaster losses continue to rise and insurers are increasingly able to discriminate risk at a policy level, will there be an increasing demand for government pools and will these stymie risk reduction efforts that risk-based premiums should in theory encourage? The increasing challenge in the future is how to increase societal resilience in the face of future catastrophic events in a fair and affordable manner. At least in the case of those government pools examined here the evidence is mixed: either because of political pressure they are actuarially unsound and end up creating a continuing liability to governments, or in failing to price individual risks correctly they encourage property development in risky locations, e.g. some coastal locations in the US, and fail to provide incentives for retrofitting older properties at high risk.

On the other hand the imposition of risk-reflective premiums by the private sector insurers will inevitably lead to situations where they may choose not to insure certain households or only at costs that many may find unaffordable. Although it would be a mistake to imagine that those, or even most of those, living in vulnerable locations are poor, the reality, given varying socio-economic demographics in vulnerable locations, is that the next major event will likely find significant numbers of impacted homeowners without insurance and with an expectation of emergency financial aid from government. In New Zealand, there has been no succour for those in Canterbury who had chosen to self-insure (uninsured). This is easier politically when most homeowners are insured as is the case in New Zealand and Australia and avoids the tendency of acts of post-event generosity by government to further reduce incentives for homeowners to take out insurance.

The dilemma outlined above is well known, but resolving it is not easy. In fact it does not seem possible to arrive at a definitive conclusion about the merits of government pools vis-à-vis private sector insurance. Although not reviewed here, some cantons in Switzerland operate government schemes while others rely on the private insurance industry for catastrophe cover and each no doubt believes it is doing the best for its inhabitants [71]. Benefits and problems will only emerge in the wake of a major disaster and depend very much upon the details and local implementation of the funding arrangements. In the absence of any obvious solution, we conclude with three observations:

First, a reminder that insurance is primarily about the accurate pricing of risk and risk transfer and, *except* in a financial sense, is not a risk-reduction mechanism per se. The authors do not see insurance as an instrument of social policy. On this point, we are in agreement with the submissions by Marsh Ltd., an insurance broking company, to a UK parliamentary Environment Committee on household insurance [31]. O'Neill and O'Neill [54] take a contrary position.

Secondly, and despite the last point, risk-reflective insurance

premiums can serve as a signal to all actors about natural peril risks. Insurance premiums are not the only way of providing transparency on the cost of risk but private insurers are the only ones with an immediate financial incentive to acknowledge such costs. Moreover insurers are the only entities that can reward policyholders when risks are reduced. In the absence of legislation, it is difficult to imagine widespread risk reduction activities taking place without risk-reflective premiums [45].

Lastly, at least in Australia, it is local governments that are ultimately responsible for land use planning decisions and it seems curious that they remain largely unaccountable for these. In short it is salutary that Gilbert White's 1945 thesis that "Floods are an act of God, but flood losses are largely an act of man" [73] still rings true, and for a wider range of natural perils than just flood.

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