Climate Risk Management 2 (2014) 1–10

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

The robustness of flood insurance regimes given changing risk resulting from climate change

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ARTICLE INFO

Article history:
Available online 29 March 2014

Keywords:
Insurance and risk
Floods/prediction planning
Adaptation
Climate change
Disaster risk reduction

ABSTRACT

The changing risk of flooding associated with climate change presents different challenges for the different flood insurance market models in use around the world, which vary in respect of consumer structure and their risk transfer mechanism. A review of international models has been undertaken against three broad criteria for the functioning and sustainability of a flood insurance scheme: knowing the nature of the insurable risk; the availability of an insurable population; and the presence of a solvent insurer. The solvency of insurance markets appears strong, partly because insurers and reinsurers can choose to exclude markets which would give rise to insolvency or can diversify their portfolios to include offsetting perils. Changing risk may threaten solvency if increasing risk is not recognised and adjusted for but insurability of flood risk may be facilitated by the use of market based and hybrid schemes offering greater diversification and more flexibility. While encouragement of mitigation is in theory boosted by risk based pricing, availability and affordability of insurance may be negatively impacted. This threatens the sustainability of an insurable population, therefore the inclusion of the state in partnership is beneficial in ensuring continuity of cover, addressing equity issues and incentivising mitigation.

Introduction

It is generally accepted that our climate is changing and the resulting hydro-meteorological variations could cause variations in risk from sea level rise, extreme weather and hazards (IPCC, 2012). Flooding is the most prevalent natural hazard event, occurring frequently across all continents (EM-DAT, 2012). Insurance against the impact of flooding would therefore benefit a significant proportion of the global population and yet much of the worldwide flood damage remains uninsured.

Partly this is because appropriate and affordable flood insurance is not widely available. Insurance against the existing extent and severity of flooding is more problematic to price than other hazards due to the uncertain behaviour of flood waters in urban environments. At a global level there is a great deal of uncertainty about the scale and timing of potential climatic changes, dependent on the assumptions inherent in predicting future climate drivers, particularly the economic scenario chosen (Solomon and Qin, 2007). This uncertainty in itself presents a challenge for those in the business of insuring flood risks in the future. Flood risk is categorized as low probability/high-consequences and with spatial correlation across

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http://dx.doi.org/10.1016/j.crm.2014.03.001
2212-0963/

losses. Therefore highly detailed information is necessary to price flood risk accurately and investment in this information may be a barrier to new entrants in the market, particularly for private companies in small markets (White, 2011). Changing climates bring extra challenges because in downscaling global climate models to appropriate spatial scales the forecasts become inherently less precise (Lopez, 2012; IPCC, 2012). These issues have led to the view in some markets that flood risk is so problematic to insure that the market alone cannot provide universal cover (Swiss Re, 2010a).

Low affordability also restricts levels of insurance coverage, particularly in emerging economies where spare resources for insurance premiums are non-existent (Churchill, 2006; Swiss Re, 2010b). Potentially, changes in flood risk associated with climate change, could make this significantly worse. Particularly germane in this respect is the expected increase in the extreme events that cause large single losses, lift the probable maximum loss threshold, and may trigger premium increases in areas affected.

This paper examines whether a changing climate is detrimental to the provision and functioning of flood insurance and which approaches are relatively more or less vulnerable to future climate risks. The comparison of approaches encompasses insurability of risk, affordability of cover, solvency of insurers, and the role of insurance in stimulating risk reduction. The first section below briefly touches on the coverage of flood insurance worldwide. The three basic requirements for sustainable flood insurance arrangements are discussed and a broad categorisation of approaches presented. This is followed by an assessment of the robustness of the approaches to the challenges of changing risk.

Context

Reported global economic losses from flooding have increased in recent decades from an annual median average of about $0.5 billion in the 1980s to around $20 billion in the first decade of this century (EM-DAT, 2012). The majority of losses are not covered by insurance, varying from less than 1% in countries such as Taiwan to almost 100% in exceptional countries such as Spain and Switzerland (Table 1). On the whole developed nations have higher coverage rates whereas insured losses in developing countries rarely represent more than 25% of total economic losses (Jha et al., 2011).

In predicting climate impacts on flood risks the expectation from the latest IPCC report (IPCC, 2012) is that global rainfall will remain fairly constant, but some regions will experience more rainfall and others less (Christensen and Hewitson, 2007). This means that national insurers in some countries may be facing rising losses due to wetter conditions, for example in the UK. Even in regions where average rainfall remains stable or declines, incidence of extreme rainfall events is expected to increase and seasonal rainfall distribution is predicted to change. Few regions or countries have taken the step of translating these IPCC climate forecasts into detailed flood damage estimates, a notable exception being the UK Foresight report which estimated that the increasing risk of urban flooding in the UK alone might cost from 1 to10 billion pounds a year by 2080 (Evans et al., 2008; Office of Science and Technology, 2003).

Observed increases in flood related damages are not due wholly to changing climates. Analysis shows that past growth in losses can be largely explained by changes in the reporting of events, increased wealth and larger populations exposed to hazard (Pielke, 2006; Crompton and McAneney, 2008; Swiss Re, 2010a; Munich Re, 2011; Barthel and Neumayer, 2012). In the short term, growth is expected to follow a similar pattern, with exposure a more important driver than climate change (IPCC, 2012). Thus it is crucial to consider the potential of insurance to encourage redistribution of exposed assets and thereby contribute to risk reduction or moderate its growth. Schemes that enhance risk reduction will remain more affordable in the future and be less sensitive to changes in climate.

Definition of key requirements

A functioning and sustainable insurance scheme requires that there is an insurable risk that is quantifiable, distributed, and affordable. It also requires that there is an insurable population aware of risk, willing to insure and one that that can afford the necessary premiums (Walker et al., 2009; Dlugolecki et al., 2009). Finally, what is needed is a solvent insurer that is willing and can afford to run the scheme and pay claims; and has arrangements in place to cover any abnormally large losses (Walker et al., 2009; Monti, 2009; Cummins and Mahul, 2009; Dlugolecki et al., 2009).

Looking forward in time there are significant threats to the viability of flood insurance regimes. Climate change threatens insurability – a combination of our first two requirements – because uncertainty means that the hazard will be less quantifiable, could be more subject to clustering of claims and less affordable because, due to increased uncertainty and clustering, premiums may increase more rapidly than the incomes of those at risk. In this respect there is a balancing act: climate change raises awareness and willingness in populations to insure but threatens the affordability and availability of cover (Aseervatham et al., 2012).

Taking the last of the three criteria – the solvent insurer – most insurance is based on for-profit companies that generally only provide cover if it is beneficial to the company to do so. Given that many insurance policies renew annually withdrawal can be swift. Market based insurers may choose to withdraw new cover at any moment unless there are agreements or legislation tying them in (Bouwer et al., 2007) and exisiting policyholders will find it hard to renew. This has happened in the United States on a large scale (Mills et al., 2005) and in the United Kingdom on an individual insurer basis (Stevenson, 2002). Withdrawal becomes more likely if, due to climate change, the cost of capital to support risk portfolios rises with increased uncertainty and larger probable maximum losses (Dlugolecki et al., 2009) and profitability is threatened.

Table 1
Features of flood insurance worldwide.

	The cover available	Coverage	Source
Austria	Private/optional Catastrophe fund for disasters covering up to 30% of private loss	10–25%	CCS (2008) Gaschen et al. (1998) Bouwer et al. (2007)
Australia	Some flood risks covered by default others available in some areas	50–60% But lower in high risk areas	IAG (2012) NDIRP (2011)
Belgium	Bundled private with fire cover up to a limit Disaster fund	High	Bruggeman et al. (2011)
Brazil	Bundled into general private buildings cover	Low linked to low property insurance	Gaschen et al. (1998)
China	Included in standard fire policy private and state owned	Low and mainly in urban areas	Gaschen et al. (1998)
Canada	Very limited private cover available	Almost none	CCS (2008) SwissRe (2010a)
Caribbean	Cover provided by private companies, State provides disaster relief via the CCIFR	Very low	CCS (2008) Auffret (2003)
Czech Republic	Voluntary add onto fire cover	15%	Gaschen et al. (1998)
Denmark	Compulsory coastal flooding cover Bundled into fire policies	50–75%	Machetti (2009) Bouwer et al. (2007)
Ecuador	Within standard fire policy private provision	Low related to low property insurance coverage	Gaschen et al. (1998)
France	Bundled in natural hazards, Public Private Partnership	Close to 100%	Gaschen et al. (1998)
Germany	Optional private add on priced by defined flood zones	5–10% in most regions	Machetti (2009) Thieken et al. (2006)
Hungary	Private Bundled cover from national and international providers	60% but much lower in highest risk zones	Bouwer et al. (2007) Vari et al. (2003)
Iceland	Compulsory natural hazards cover includes flood	100%	CCS (2008)
Indonesia	Supplement to fire policy privately or state owned	20%	Gaschen et al. (1998)
Israel	Optional to fire policy. Private cover	95%	Gaschen et al. (1998)
Italy	Option as an endorsement Disasters often covered by emergency taxes	<5%	Gaschen et al. (1998)
Japan	Available within comprehensive fire cover which is an optional extension Private provision	40% -72%	Gaschen et al. (1998) Kron (2009)
Mexico	Private cover based on risk zones Emergency relief provided by FONDEN	Low	Monti, 2009
Netherlands	Pluvial bundled in standard policy Fluvial and coastal not available	High Non existent	Bruggeman et al. (2011)
New Zealand	Part of earthquake cover compulsory	High	Paklina, 2003 CCS (2008)
Norway	Compulsory as part of property policies, backed by national pool backed by reinsurance	High above 75%	Bouwer et al. (2007) Machetti (2009) OECD (2003) CCS (2008)
Philippines	Part of typhoon cover to fire policy private provision Government often provides relief funds	10–20%	Gaschen et al. (1998)
Poland	Private add onto Fire cover. Private companies	25%	Gaschen et al. (1998)
Portugal	Included in natural perils as part of fire cover	High due to bundling with earthquakes	Gaschen et al. (1998)
South Africa	Add onto fire cover private provision but not available in highest risk areas	30–50% households but 75%+ by value	Gaschen et al. (1998)
Spain	Bundled into all buildings cover	Close to 100%	Gaschen et al. (1998)
Switzerland	Standard part of buildings cover state provided	100%	Gaschen et al. (1998)
Taiwan	Part of typhoon private provision	Less than 1% due to high rates	Gaschen et al. (1998)
Turkey	Some might be covered under earthquake	Very low	Paklina, 2003
UK	Bundled in general household	95%	Gaschen et al. (1998)
US	Optional state provided	75%	Abbott (2008)

However, considering insurance as a completely commercial transaction is too narrow a perspective. It can also be argued flood insurance provides a social good (Association of British Insurers, 2005) as it contributes to social and financial stability; enables quick recovery from damaging events; and may also address social equity by assisting the most vulnerable (Priest et al., 2005; Zsamboky et al., 2011). An insured population may also be seen as desirable in the short term because moving everyone out of the hazard zone to reduce exposure and potential losses is not practical. If insurance is seen as a social good then the role of the solvent insurer could be fulfilled by the state or a donor organisation. Commercial insurance schemes that have some measure of solidarity and cross-subsidy also exist and there may be some rationale for this to continue, in terms of reputational gain, maintaining and growing market share and market size.

Climate change threatens the solvent insurer because the potential to suffer larger or unexpected losses leads to a greater likelihood that flood insurance companies and markets will fail, as they have in the past (Burby, 2001) when cover has been

provided that leads to claims in excess of the companies' ability to pay. It follows that markets that will be less likely to fail due to climate change will include those schemes that have risk transfer mechanisms that are robust to greater uncertainty, to possible clustering of large losses, to larger average losses and to higher probable maximum loss and which encourage mitigation.

Analysis of approaches

Approaches to the provision of flood insurance are categorized below under five descriptive variants linked to the status of the primary provider (private or state), risk transfer mechanisms and the securitisation of risk. Schemes were selected based on illustrating the type of schemes and potential challenges and strengths of the scheme type rather than being a representative sample of worldwide schemes. They are analysed using the three requirements, given above, as some sort of "benchmark" with the caveat that schemes are continuously undergoing review and amendment, reflecting the fact that improvements are sought in flood insurance across the globe and that many system remain imperfect. The four main international models are also summarised in Table 2 in respect of sustainability via their robustness to climate pressures of uncertainty, clustering and higher losses and their encouragement of mitigation in Table 2.

Bundled insurance backed by private markets and reinsurance

Flood insurance that is included by default within a general property insurance policy is referred to as 'bundled'. Where this is provided and underwritten by the commercial market it is categorised as private or market-based. Bundling is one way to promote high penetration of cover, maximising the population willing to insure, as in Hungary where private flood cover is bundled within residential property insurance, reaching almost 60% of households (Vari et al., 2003). Bundling is particularly effective if mortage finance is conditional on property insurance as in Israel (Smolka, 2006) and the UK (Lamond et al., 2009). Conversely in China, and Ecuador, although flood risk is included in most fire policies, coverage is low reflecting low household insurance penetration (Gaschen et al., 1998).

Often in a bundled system the price of insurance is not related to flood risk with significant cross-subsidisation from households in low-risk areas. This contributes to affordability and increases the population willing and able to insure. Bundling can also enhance diversification of risk across perils with small incremental increases in flood premium masked within a larger policy bundle. It also obviates the attribution problem as insurers cannot claim that the damage was due to some other peril such as wind in order to avoid paying claims. If the cross-subsidy can be maintained in the face of increased claims caused by climate change then affordability may be sustained. In addition the unpredictability of changing patterns of risk may be sensibly absorbed within diversified bundle.

Table 2
Types of schemes benchmarked against sustainability indicators (bold type indicates positive aspect).

Criteria	Bundled private	Add-on or separate policy private	Bundled State	Add on or separate policy State
Robust to uncertainty	**Access to international risk/ money markets Coverage level boosted through link to other perils Diversity across perils** Insurers can withdraw from market	**Access to international money markets** Insurers can withdraw from market Coverage may be lowest Premiums may increase with uncertainty Adverse selection	**Access to state funds/tax base. Coverage level boosted through link to other perils Diversity across perils**	**Access to state funds/tax base.** Coverage may be low due to lack of perceived need. Adverse selection.
Robust to clustering	**Diversity of risk across perils, Diversity of risk across markets**, Clusters may cause insurers to withdraw	**Diversity of risk across markets**, Premiums may be volatile causing lack of affordability Clusters may cause insurers to withdraw	**Governments less likely to withdraw suddenly Diversity of risk across perils**, Clusters may put strain on national ability/willingness to pay	**Governments less likely to withdraw suddenly** Clusters may put strain on national ability/willingness to pay Premiums may be volatile causing lack of affordability
Robust to potentially rising loss	**Independent of state credit rating Bundling can mask flood losses** Competition can lead to underpricing of risks Insurers can choose to withdraw	**Independent of state credit rating Rising loss may bring greater awareness and boost coverage** Competition can lead to underpricing of risks Insurers can choose to withdraw	**Government can elect to subsidise and refinance** Depends on PML relative to GDP and solidarity Government may not have the incentive to fully evaluate risk	**Government can elect to subsidise and refinance Rising loss may bring greater awareness and boost coverage** Depends on PML relative to GDP and solidarity
Encourages Mitigation	Lack of explicit flood premium reduces incentive (moral hazard). Competition can lead to short termism	**Explicit flood premium increases incentive** Competition can lead to short termism	**Government can impose conditions for cover Government can invest in reducing future claims** Lack of explicit flood premium reduces incentive (moral hazard)	**Government can impose conditions for cover Government can invest in reducing future claims** Potential to choose not to insure to avoid premium

However, if flood risk is the dominant peril and the cross-subsidy is not maintained then availability and affordability will be limited in high risk areas. In these circumstances bundling can result in loss of cover for other perils. For example in Hungary's high risk Upper Tisza region only about 4% of the households hold property insurance (Vari et al., 2003).

The potential that climate change induced growth in claims could lead to further limits on supply or destabilize markets is one of the major weaknesses of market based insurance. In the 1990s after massive claims from hurricanes in the Caribbean, insurers considered pulling out (Pelling and Uittob, 2001), despite the fact that claims could be absorbed within available reinsurance capacity (Laframboise and Loko, 2012). High claims are not necessarily a problem if premiums can be increased and capital reserves from a wide international reinsurance base can be accessed. In the case of the Caribbean the international market eventually designed a special policy for small island states (Pelling and Uittob, 2001). Furthermore if rising claims levels can be mitigated by flood risk reduction measures, preparedness and property resilience, then insurance profitability may be maintained.

These challenges are in part addressed by the UK flood insurance scheme often seen as a model of private public partnership (Swiss Re, 2010a). Private insurance companies provide cover with the understanding that flood risk reduction act will be pursued by the government. It has been observed (Lamond and Penning-Rowsell, 2011) that the regime is fairly successful in risk transfer, partly because of the geographical dispersion of UK flood risk over the whole country, and the 1961 'Gentlemen's Agreement' which led to substantial flood risk management expenditure over many years. However the UK model encourages moral hazard (that it is insulates the person or organization at risk from the full consequences of the hazard thereby reducing the need for them to take care to reduce the risk) and fails to provide sufficient incentives for mitigation, either governmental or private (Dlugolecki et al., 2009; Lamond et al., 2009), making the model less robust to increasing risk. Bundling and cross-subsidisation can be obstructive to the aim of incentivising risk reduction, particularly if reporting of claims fails to provide adequate feedback on risk distribution.

Bundled insurance backed by the state

State backed insurance is categorised here as cover where the risk is transferred eventually to the state although the policies may be issued via either private companies or state organisations.

In this category commentators have highlighted the French National Catastrophe model as a highly successful scheme which involves state backed insurance achieving high flood coverage (Michel-Kerjan, 2001). The recent changes to the Belgian insurance provision, legally instituting natural disaster cover as part of simple risks in 2005, is modelled on the success of this scheme (Bruggeman et al., 2011) with the distinction that only those at risk from flooding need to pay the endorsement (Van Den Bergh and Faure, 2006).

The French system is based on a risk pool for all perils and is Government backed through the CCR (Caisse Centrale de Reassurance). Cover is mandatorily included in property cover and flat rate additional premium is collected by direct insurers. A proportion of the premium is passed to the pool depending on the percent of risk the direct insurer underwrites in house or reinsures privately. The mandatory nature of cover ensures a large insurable population and the flat rate cross-subsidisation contributes to affordability. Once the government has announced a state of national disaster then property damage directly due to that disaster is covered but indirect costs such as re-housing are not included (CCS, 2008). A similar arrangement exists in Denmark (Machetti, 2009) and in Spain where natural hazards, including flooding, are covered by a publicly backed corporation, the CCS (Consorcio de Compensacion de Seguros). A percentage of all insurance premiums is paid to the fund to cover losses and the Spanish Government guarantees the fund against failure effectively acting as a reinsurer and ensuring solvency by covering losses above a certain level (Auffret, 2003).

Since its inception the rules and rates pertaining to French reinsurance contracts have changed as a response to demand from insurers and major natural disasters which have drained the CCR. The fund is secure because the State will make up deficits from tax revenue and climate change is likely to increase the demand on the state as the pool suffers more frequent depletions. Recently there have been questions raised about the sustainability of the solidarity system in the light of improved hazards assessment (Lamond and Penning-Rowsell, 2011). However one benefit of the scheme in covering all perils (not just flood) is that those not at risk of flood may benefit from insurance against other perils.

One of the disadvantages of state backed bundled systems based on solidarity is that there is no premium incentive for mitigation or disincentive for the construction of property at high risk, weakening sustainability. However if claims start to rise there will be a direct incentive for government to intervene and fund or encourage risk management. The state also has the potential to restrict floodplain development through planning legislation. In France, communities are encouraged to mitigate risk via community flood risk plans and there is also a fund (the Barnier Fund) available to purchase houses in the wake of disasters and compensate the owners (Fiselier and Oosterberg, 2004).

State backing of flood insurance enhances the willingness of insurers to enter the market. Focus on social benefits and the protection of the vulnerable is another positive feature of state backed schemes that market provision would struggle to emulate. The crucial test is whether such pools can continue to be backed by state resources if claims rise significantly with changing climates. Where the national economy can bear the PML – whether via a national pool, the tax base or borrowing after an event – this can be a lower cost option than market based reserves. However it will be increasingly the case that reserves to cover the PML could be beyond the national capacity and therefore recourse to international markets via catastrophe finance will be required. Catastrophe finance can provide a backstop to individual insurers or governments via catastrophe bonds (Bonds that will fail to pay back to investors if an event of an agreed magnitude occurs. This allows the issuer to

use the invested money to pay claims or repair damage) or reinsurance (a policy that pays out proportional to the losses if an event if agreed magnitude occurs).

Hybrids of market and state backing may also be resorted to, such as in New Zealand, where insurance for flooding is handled by the Earthquake commission (EQC) under state guarantee (CCS, 2008). This system covers all residential properties against natural disasters automatically under the fire insurance policy, ensuring low cost, universal cover, although individual residential claims have been capped. The EQC underwrites claims either directly or through insurance entities (Machetti, 2009). A natural disaster fund is held under the control of Ministry of Finance in order to make adequate resources available in case of a major disaster. Liquidity of the fund is enhanced by reinsurance arrangements for liabilities between NZ$1billion (£0.5 billion US$0.8 billion) and NZ$4 billion (£2 billion, US$3.2 billion). Beyond that level the EQC is covered by provision of state grant or loan (CCS, 2008). The Norwegian loss pool system goes one step further and reinsures everything in an excess of loss treaty ensuring that any losses above the excess amount are covered by reinsurance (CCS, 2008). Reinsurance is also involved in the Icelandic Catastrophe Insurance pool covering sea and glacial melt flooding. However, this pool reserves the right to reduce pro-rata all claims payments if the claims rise above a proportion of the sum insured and to take out state backed loans to cover claims (CCS, 2008). In Brazil the government's Instituto de Reseguros used to have a monopoly in the country's reinsurance industry and still holds the majority share (Auffret, 2003). As claims patterns change it will be incumbent on the managers of perils pools to make sensible provision to cover future losses and the use of international financial instruments will be likely to increase with increasing uncertainty.

Separate or add-on private cover, backed by reinsurance

Separate or 'add-on' policies cover flood risk either separately or as part of a natural hazards policy, but not as part of fire or theft insurance. The distinguishing feature is that policies are 'opt-in' and take up is dependent on risk awareness and the acceptance of the need for insurance. Awareness of risk is one of the few aspects of insurance markets that may improve due to changing climates as worry about the future may encourage insurance take up. Pricing is likely to be risk based because competition will drive prices to the lowest level in each risk zone, minimising cross subsidisation.

Market penetration will tend to be lower for add-on schemes, as for example in the privately provided German natural hazards endorsement which includes floods and torrential rainfall. Storm surge cover, insurance for storm water drainage problems and to a very limited extent groundwater flooding is also available (Thieken et al., 2006). Private insurers offer cover at market based pricing but uptake is low with about 10% of the population holding cover. There is the potential for this cover to avoid the phenomenon of moral hazard by incentivising mitigation (Kunreuther, 2002). However Thieken et al. (2006) found that few companies took the time to make individual risk assessments or impose special conditions with regard to flood risk. Where hazard awareness is higher such as in South Africa natural perils cover is widespread within insurance holders due to high hazards awareness but only 30–50% of households have property insurance for any peril.

A further danger for opt-in policies is adverse selection, that is the effect when only the very worst risks will seek cover. This is seen in Austria where the resulting high premium cost in flood risk areas ensures penetration remains low (CCS, 2008) and in Taiwan. To avoid adverse selection, private insurers will tend to exclude potentially insurable risks as they have little incentive to take risks or invest in detailed evaluation of individual policyholder's circumstances. This is apparent in the German zoning system where actuarially priced cover for very high risk property, defined as flooding more than once every ten years (estimated at about 2% of policyholders), is difficult to obtain and this is likely to become worse with climate change induced greater risk. In response, a recent initiative from the German Insurance Association (GDV) will provide a certificate of insurability to assist the households now unable to find cover.

Where flood is a small part of natural hazard risk, inclusion within a natural hazards policy improves risk diversification, increases penetration and improves affordability as in Portugal (Gaschen et al., 1998). This is also seen in Japan where flood insurance is privately supplied add-on cover within a natural risk policy including volcanic eruption, storm and earthquakes. Roughly 2% of the total hazard damage is due to flooding and therefore the insurance regime is highly tailored to earthquake cover. Less than half of households hold insurance but due to adverse selection a larger proportion of potential damages (70%) are estimated to be insured (Kron, 2009). Conversely if cover for other hazards is unaffordable then flood insurance penetration will suffer.

Add-on or separate policy, state-backed: the US model

State (or donor) involvement in provision of insurance facilitates provision of cover to the most vulnerable who can be specifically targetted through add-on policies. For example to address a shortfall in insurance coverage in the Indonesian capital Jakarta – which suffers regularly from flooding – a micro insurance product was offered by an Indonesian German partnership on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ). Unfortunately, despite the simplicity of the product the cost was seen as too high and the product was discontinued. In contrast a micro insurance product in the Philippines was designed to provide reconstruction funds after typhoons (Karlijn Morsink et al., 2011) to low income households. The take up has grown such that 130,000 policies were underwritten by 2010.

State-backed schemes can instigate incentives for risk reduction activities due to lack of competition (Lamond et al., 2009) and specificity to hazards, although the experience of the American National Flood Insurance Programme (NFIP) shows it is hard to achieve. The NFIP arose in 1968 from American Insurance Association findings that, due to the potential for

adverse selection, private insurance could not provide adequate cover in vulnerable areas (Federal Emergency Management Agency, 2011). The NFIP had the dual aim of helping individuals to bear the risks of flood damage and discouraging unwise occupancy of flood prone areas by limiting development (Secretary of the Department of HUD, 1966). Subsidisation creates affordability and the mandatory nature of cover boosts penetration to an estimated 75% of those legally required to hold cover. However, to control the scheme's exposure, cover is limited to direct damages and is capped at US$250,000 per property (Abbott, 2008).

One disadvantage of add-on provision is that incorrect designation can leave households exposed to uninsured risk. In the US 50% of damages occur outside the official hazard areas, and only 1% of these are covered by flood insurance. Increased pluvial flooding, a projected feature of changed climates, often occurs outside designated zones and may lead to more uninsured damage. A less affordable private market for flood insurance also exists to top up the capped cover and for property which is not eligible for NFIP cover.

However, the major problem with the approach is the cost. Forty years after it started (and before the recent events in New York) the US government subsidy amounted to over $17.5 billion. Political pressure and legal challenges have limited actuarial pricing and the scheme has not prevented high risk development. Repetitive claims are common and 1% of properties represent 30% of claims. FEMA has explored options including allowing local communities to invest in flood protection or softer measures in exchange for lower priced cover (Federal Emergency Management Agency, 2011). Recent flooding in New York has sharpened the desire to address the funding shortfalls. The changes now announced for the NFIP include moving towards actuarial pricing for all new policies and requiring elevation certificates as a condition of cover. The inevitable financial limits of a state backed guarantee may lead to availability issues as costs rise. Changing risks need to be backed by increased levels of funding but national governments may not be prepared for higher levels of claims.

Where flood insurance is not generally available

Flood cover may be unavailable for many reasons but authorities in countries where flood cover is not widely available increasingly seek to introduce it. For example in Turkey there is a recognition that with growing flood risk it may become necessary to include flooding in the existing earthquake pool (Ladbury, 2012).

Insurability is the main barrier to provision in Canada where flood cover is excluded from the majority of standard home insurance policies (Swiss Re, 2010b). Previous assessments of the potential to introduce flood insurance in 1976 and 1983 determined that rates would be prohibitive or would require heavy government subsidy. Recently the Insurance Bureau of Canada concluded similarly that the small numbers of potential policy holders makes the provision of cover difficult (Insurance Bureau of Canada, 2010) and a pilot project in Winnipeg failed after 2 years because only 30 people signed up. A recent Swiss Re report recommended bundled insurance similar to the UK example but with built in risk based premium and deductibles (Swiss Re, 2010b).

Perceived insurability has also been an issue in Australia where flood risk is ever present but a low percentage of properties (2.8%) are at risk. Cover for river flooding is subject to adverse selection and therefore usually unavailable or unaffordable for those at high risk. Coastal and storm surge insurance is rare but insurance for flash flooding is widely available and has a relatively high penetration (60%) (CCS, 2008).

The situation is changing as changing weather drives increases in damages related to intense rainfall and pluvial flood events. Since the 2011 Queensland event, improved cover has been introduced in some states (Insurance Australia Group, 2012), but the inclusion of some flood types and the exclusion of others has resulted in confusion for homeowners and businesses (Queensland Flood Commission of Enquiry, 2012). The view of the industry and the recent Commission enquiry is that flood is a technical term not well understood by the policy holder (Insurance Australia Group, 2012). The Australian government has been considering the restructuring of the flood insurance market for some time and is investigating the use of catastrophe bonds and other measures (Jha et al., 2012; National Disaster Insurance Review Panel, 2011).

Another rationale for non availability of flood insurance occurs when damages are expected to be covered by another source. In the Netherlands flood insurance is not available for the major hazards of coastal and fluvial risks as a result of government guarantees and compensation schemes put in place during the post-1953 investment in flood defences. Cover against extreme rainfall events is included within most household policies (Spekkers et al., 2012). Climate change and sea level rise has caused the Dutch to re-evaluate the provision of flood guarantees and the potential to introduce commercial cover and from October 2012 an experimental fluvial cover scheme is being introduced (Spekkers et al., 2012).

Elsewhere there is a greater reliance on aid and the incentive to insure is reduced by the expectation of emergency relief. Damage in Italian floods is often covered by state compensation payments, leading to very low demand for insurance (Gaschen et al., 1998). The Mexican state backed disaster fund or FONDEN to aid to victims of major damaging events such as earthquakes or massive floods lowers the demand for the available private offering (Monti, 2009). The fund has existed for decades but suffered from underinvestment in between events. Since 2006 the issuance of catastrophe bonds has allowed the fund to continue to operate regardless of major events (Jha et al., 2012).

The affordability of catastrophe finance relates to the cost of disasters and the size of the national economy. The Czech Republic and Poland face risks greater than 2% of their GDP and are therefore vulnerable to major events (Bouwer et al., 2007) and in the Eastern Caribbean damages amounting to around 2% of GDP are expected every 2–3 years (Laframboise and Loko, 2012). An inter-country pooling option was pursued by CARICOM (the Caribbean Community and Common Market), set up with the assistance of the World Bank and Japanese government to cover all natural hazard risks. The fund

is used by the government to aid reconstruction and a limited amount of private flood losses as a result of major storms and hurricanes would be relieved by the scheme (Jha et al., 2012).

Conclusions

Climate change is a challenge to the sustainability of flood insurance because increasing variability of flood hazards could lead to much higher maximum losses and more unpredictable claims patterns. Our analysis in this paper shows strengths and weaknesses of various risk transfer mechanisms and identifies that changing future flood risk patterns will provide important tests for each of three necessary requirements of functioning insurance markets: insurable risks; an insurable population; and solvent insurers. The ability of schemes to accommodate these challenges will vary according to their approaches to this risk transfer issue.

In the insurance markets described above, financial stability of the primary insurer is strong because risk transfer is used to guarantee their ability to meet claims. In this respect, three basic risk transfer mechanisms emerge: the state; the private reinsurance market; and some form of catastrophe finance. The potential to transfer risk is linked to the insurability of the risk, the size of the insured population, distribution patterns of risk and the tendency for adverse selection. Risk transfer becomes problematic when the probable maximum loss is high relative to the potential for premium income, for example in very high flood risk situations, low income economies or for those subject to low probability but high-consequence flood events. Lack of predictability can also be problematic such as increases in storminess predicted as a result of climate change generating wilder extremes in weather and claims in previously risk free areas. Diversification across hazards or geographies leads to higher transferability of risk. Our analysis suggests that uncertainty and clustering due to climate change will therefore markedly increase reliance on international reinsurance markets, catastrophe bonds and other financial instruments to offset increased unpredictability, wider extremes and higher regional risks.

However demand for insurance will be restricted by affordability and the actuarially based cost of market provided cover may become increasingly unaffordable for individuals at highest risk. In this situation, should policy dictate that the urban use of flood risk areas must be maintained, government or donors will need to step in with cross-subsidised insurance or post disaster aid.

Cross-subsidisation from areas at lower risk to those at higher risk can form part of a privately backed scheme particularly if flood insurance is bundled with other cover, However, as claims rise, whatever the cause, and information on hazard improves, competitive pressures on insurers leads inexorably towards risk based pricing. Those insurers that do not price risks actuarially will be at risk from adverse selection and may suffer large claims deficits. Therefore affordability and availability of provision can be better supported by a state backed scheme, if the state can bear the probable maximum loss, and can lead to wide coverage and affordable cover for the poorest and most vulnerable.

Risk awareness and demand for insurance is likely to increase with changing weather patterns and sea level rises causing unexpected pluvial, fluvial and coastal flooding. Conversely lack of insurance availability already affects a large proportion of at risk populations and changing flood risk will exacerbate the reluctance of private insurers to extend provision. Withdrawal of market players is possible in the future, and this may force state intervention to maintain the viability of existing settlements in the floodplain. The control of non hazard based risk factors and the mitigation of flood risk will be crucial.

Pools such as the French, Spanish and US systems developed on historic risk based premium income may become inadequate due to climate change. State guarantees could result in large demands on the taxpayer on a regular basis. For smaller economies that lack the GDP to guarantee their own risk portfolios international catastrophe pools have been seen as an option. Although there may be a need for international donor support to set up such funds, in the long term they may become self-perpetuating and qualify for market finance.

Structure of cover is also very relevant to stability. Bundling of flood with other perils facilitates economies of scale and lowers the ratio of maximum loss to premium income, thereby reducing demands on capital reserves. Single peril schemes may exhibit correlated losses and induce insolvency. Bundling can also contribute to affordability and availability as climate change may not have such a large impact on the totality of hazard cover as it does on flood risk. Add-on or single peril schemes, by making subsidies transparent, are more likely to be actuarially priced and less affordable for those at most risk. Conversely, bundling sometimes results in populations that cannot afford flood cover becoming exposed to other perils.

In conclusion, no single approach to flood insurance answers all challenges inherent in changing climates. The design of workable schemes is highly specific to the existing risk context for flood and other perils and likely future risk scenarios. Each arrangement has weaknesses and there is tension between the short term goal of ensuring solvency of insurers, and therefore secure recovery funding, and the long term goal of reducing risk for all. Careful evaluation of any insurance scheme against social and financial objectives is therefore necessary, and a multi-stakeholder consideration of options based on the best available climate predictions and the longest possible historic risk profiles is recommended. In this way the strengths and weaknesses can be properly assessed in the local context, and the over-riding imperative of solvency can be balanced against societal needs for comprehensive provision and improved mitigation practice. In the last analysis failure to recognise the potential for climate change to invalidate existing systems carries a fearful potential burden of future unprotected damage.

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