Chapter 3

Insuring flood risk

This chapter provides an overview of insurance arrangements for covering flood risk across countries, including the role of private insurance markets and governments in providing coverage, the form of insurance coverage available, and the level of coverage. It identifies the significant "financial protection" gap that exists for flood risk and outlines the factors that make flood risk a particularly difficult peril to cover.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

There is a wide variety of approaches across countries to protecting households and businesses against flood risk. In many countries, private insurance companies offer coverage for flood-related damages and losses, either as part of standard property and business interruption policies, or available as an optional add-on to such policies. In some countries, coverage for flood damage may only be available from a public insurer, especially for properties deemed to be at high-risk of flooding. In other countries, government assistance may be the only source of compensation available for losses from flood events. In countries with lower levels of insurance market development and penetration, micro-insurance might play an important role in providing financial protection.

These different approaches to financial protection have been designed with the aim of achieving different policy objectives, such as broad availability and affordability of coverage, solidarity in terms of loss-sharing across regions, establishment of clear incentives for risk reduction and/or significant transfer of risk to private markets. There are clear trade-offs between these different approaches. For example, broad availability and affordability of coverage and/or solidarity across regions usually entails some form of cross-subsidisation across policyholders with implications for the strength of incentives to encourage risk reduction. In some instances, a reliance on private markets (and full risk-based pricing) may come at the expense of the availability of affordable coverage for high-risk properties.

3.1 Financial protection against flood risk across countries

Private insurance coverage for flood risk

The insurance coverage of flood risk in a number of OECD and non-OECD countries is exclusively or primarily provided by private insurance companies (see Table 3.1). In some countries, there may be some differentiation in terms of the type of flood perils covered (e.g. inland vs. coastal flooding, overland vs. sewer back-up, etc.). Some insurance policies may include coverage for additional living expenses in cases where the level of damage to residential structures impedes access to the property, either as an additional option or part of standard coverage. Coverage for flood damage is also available for motor vehicles in most countries, either as part of standard coverage or as an optional add-on. For businesses, coverage of property and contents for flood risk and for business interruption is the most common form of financial protection of flood risk.

Standard residential property insurance policies in a few countries (Australia (flash flooding), Austria (basic amount), Belgium, Denmark, Finland, France, Iceland, Israel, Latvia, New Zealand, Norway, Poland, Russia, Spain, Switzerland and the United Kingdom) are automatically extended to cover flood risk, usually bundled as coverage for all or most natural perils. In Japan and Turkey, flood coverage is usually included in standard residential property policies in practice (although bundling is not a formal requirement for insurers). In Switzerland, insurance coverage for residential and commercial buildings against a number of natural perils, including flood risk, is mandatory in 22 of 26 cantons (coverage for contents and motor vehicles is not mandatory but nevertheless widely used). In Belgium, insurers may not extend coverage to high-risk properties built after the completion of risk maps (Wharton Risk Management and Decision Processes Center, 2016).

Table 3.1. **Insurance arrangements for flood risk**

Country	Coverage Provider		Form of Coverage		Description
	Private	Public	Automatic extension	Optional Add-On	
indicates motor vehicle coverage; indicates residential property coverage; and indicates commercial property coverage.					
Australia					A distinction is made between damage caused by flash floods and riverine floods. Coverage for flash flooding is generally included in standard policies. Insurers are required to offer riverine flood coverage as part of standard cover, but may derogate if disclosed to the policyholder. Consumers have a wide choice of products: 86% of policies selected by consumers have flood cover as a standard inclusion, with no opt-out option; 7% of policies are sold with flood cover as an inclusion, but with the opportunity to opt-out; and 7% of policies sold derogate flood cover entirely. Flood insurance is sold on a risk-based pricing basis and is not cross subsidised.
Austria					"First risk" coverage for flood damage is automatically extended to standard residential fire policies. Extended coverage is available on an optional basis.
Belgium					Insurance companies may not extend standard policies to high-risk properties.
Canada					The availability of private coverage for flash and riverine flooding for residential property is new and not yet available for all properties (coverage for coastal flood is not available). Motor vehicle insurance, including coverage for flood risk, is provided by public insurers in some provinces.
Chile					Insurance for flood is bundled with other natural disaster perils and available as an optional add-on to standard coverage.
Costa Rica					Most flood insurance coverage is provided by a public insurer (operating similar to a private insurer) that provides various types of insurance coverage. The public insurer will not provide coverage for high-risk structures (e.g. located too close to coasts or rivers)
Czech Republic					Insurance companies are unwilling to offer flood coverage in flood-prone areas.
Denmark					A mandatory charge is attached to all fire policies and used to provide compensation for damage from storm surge and inland flooding through the Danish Storm Council where private insurers do not provide coverage.
Estonia					There is one region where flood insurance availability may be limited due to regular flooding.
Finland					Since 2014, flood insurance has been included in standard residential property coverage although coverage is only provided for damage above a certain threshold.
France					Private insurers automatically extend coverage to include natural disasters (at a flat rate) and can reinsure up to 50% of their natural disaster exposure with a public reinsurer (CCR).

Country	Coverage Provider		Form of Coverage		Description
	Private	Public	Automatic extension	Optional Add-On	
*  indicates motor vehicle coverage;  indicates residential property coverage; and  indicates commercial property coverage.*					
Germany					Standard policies exclude storm surge and flash flooding. Coverage for a set of natural perils is bundled and made available as an optional add-on.
Hungary					Insurance companies are unwilling to offer flood coverage in flood-prone areas. A public financial protection fund has been established to provide insurance for high-risk residential properties.
Iceland					ICI provides coverage for natural disaster risks, including floods, as an automatic extension to all residential and commercial property insurance policies. Coverage against fire (and therefore flood and other natural perils) is mandatory for commercial and residential property.
Ireland					Insurance companies are unwilling to offer flood coverage in flood-prone areas.
Israel					Flood insurance is part of broader natural risks coverage.
Italy					Coverage for natural disaster risks is available as an optional extension to standard policies.
Japan					While coverage for flood damage is optional, most standard fire policies include coverage for flood damage under a single premium.
Latvia					Insurance companies are unwilling to offer flood coverage in flood-prone areas or only with high deductibles.
Mexico					Flood coverage is bundled with coverage for other hydro-meteorological risks (e.g. hurricanes) as an optional add-on to standard property policies.
Netherlands					The availability of private flood insurance for residential property is new and limited.
New Zealand					The public Earthquake Commission provides coverage for damage to land in and near residential properties and access ways. Private insurers provide coverage for flood damage to structures.
Norway					The Norwegian Natural Perils Pool has been established to pool natural disaster losses among private insurers.
Peru					
Philippines					Some general insurance coverage is provided by publicly-owned insurance companies. These companies are the only providers of flood insurance for high-risk properties.
Poland					
Portugal					Insurance companies may not offer flood coverage or may stipulate unaffordable tariffs.
Russia					Insurance is not available for structures in flood zones (where in violation of construction permits). Insurance companies may exclude flood coverage in flood-prone

Country	Coverage Provider		Form of Coverage		Description
	Private	Public	Automatic extension	Optional Add-On	
indicates motor vehicle coverage; indicates residential property coverage; and indicates commercial property coverage.					
					areas.
Spain					An extraordinary risk cover clause is mandatorily included in property, life and personal accident policies, and a mandatory surcharge is applied. The risk is assumed by CCS (provided it is not assumed by the company on its own). CCS is provided with an unlimited state guarantee in case its resources are exhausted (never used).
Switzerland					Coverage for natural disaster losses is mandatory for residential and commercial buildings in 22 of 26 cantons. Insurance coverage for buildings is provided by private insurers in 7 cantons. In the other 19 cantons, natural disaster insurance coverage for buildings is provided by canton monopole insurers only. Coverage of contents is provided by private insurers in all cantons. Contents and motor vehicle insurance coverage is not mandatory.
Turkey					The coverage of flood risk is not required as part of standard fire policies although, in practice, most policies are automatically extended to cover flood risk. However, insurance companies may not offer flood coverage in flood-prone areas or may stipulate extra conditions.
United Kingdom					Private insurers can transfer risks related to their coverage of certain high-risk properties to Flood Re, an industry established pool.
United States					The National Flood Insurance Program (NFIP) provides flood coverage for residential properties in eligible communities. Private insurers may also provide alternative coverage or excess coverage for amounts above the maximum level of NFIP coverage (excess flood insurance) as well as coverage for additional living expenses (which is not covered by the NFIP).
Viet Nam					Flood insurance coverage is generally only available for motor vehicles.

Source: Most of the information was taken from country responses to an OECD questionnaire on the financial management of flood risk (2015). Additional information was also taken from UNISDR (2015), Wharton Risk Management and Decision Process Centre (2016), Maccaferri, S., J. Carboni and F. Campolongo (2012), Insurance Bureau of Canada (2015) and Swiss Re (2015b).

In other countries, insurance protection against flood risk is offered as an optional add-on to standard property policies, either as a single peril or in combination with other disaster risks. In Germany, the optional add-on is for insurance coverage against all natural catastrophes (*Elementarschadenversicherung*). Similarly, optional coverage for a set of natural catastrophes is available in the Philippines. In Austria, a basic amount of coverage for flood risk is automatically included on a first-loss basis with the option available to purchase additional coverage. In Austria, Costa Rica, Czech Republic, Ireland, Portugal, Turkey (amongst other countries), optional coverage for properties in flood-prone areas is not always available or available only with high deductibles, at high-cost and/or upon the implementation of specific risk prevention measures. In Canada and the Netherlands, flood insurance for residential properties has only recently become

available (previously, the only compensation available was provided by the public sector).

In a number of countries (Czech Republic, Portugal, United Kingdom, United States), lender practice or legislation requires some or all properties with mortgages to be protected against flood risk. In the Czech Republic, Ireland, New Zealand, Portugal, Sweden and the United Kingdom, mortgage lenders always (or generally) require borrowers to obtain insurance protection against flood risk. In the United States, federally-regulated mortgage lenders are legally required to ensure that borrowers with properties in flood-prone areas are protected by flood insurance.[1]

In almost all countries, premiums charged by private insurers vary (to some extent) with the level of risk, although with varying levels of granularity. In Switzerland, premiums charged by private insurers in the 7 cantons without a cantonal monopole insurer are established by regulation at a flat rate (although that level is established based on an assessment of overall exposure across a number of perils including flood). In other countries, limits to the capacity of private insurers to assess flood exposures and/or the practice of bundling coverage with other perils limits the alignment of premiums to the level of risk.

Public insurance of flood risk

In a number of countries, the public sector provides financial backing for the insurance coverage of flood risk, either as a direct insurer or reinsurer for all or a sub-set of properties (see Table 3.1). Iceland and 19 of 26 Swiss cantons offer bundled direct insurance underwritten by a public entity for all or most natural perils for all residential and commercial properties. In France, reinsurance for all natural disaster risks is offered by the public *Caisse centrale de reassurance* (CCR) for up to 50% of the losses, although private insurance companies are not required to purchase reinsurance from CCR. Similarly in Spain, the *Consorcio de Compensación de Seguros* (CCS) manages the "extraordinary risks" insurance coverage which offers direct insurance for flood and other extraordinary risks by means of coverage that is mandatorily included in property, life and personal accident policies issued by private companies. Private insurers may choose to retain the extraordinary risks or transfer the risk to CCS (however, should they decide to transfer these risks to CCS, they must transfer all extraordinary risks). In all these cases, insurance coverage is either mandatory or provided as an automatic extension to property, business interruption or motor vehicle policies. Premiums charged to households and businesses are generally flat (i.e. do not vary with the level of risk), although with some level of variation in the case of Switzerland according to the exposure. In France, premiums are flat although deductibles are increased for repeated claims due to the same peril in communes that do not have a *plan de prévention des risques* (risk prevention plan) (Fédération française des sociétés d'assurances, 2016).

In Korea, a public scheme (operated by a private insurance company) provides coverage for storm and flood risk to residential properties. New Zealand's Earthquake Commission provides direct insurance coverage for damage to residential land from flooding (along with coverage for residential land and structures against earthquake and several other risks). In Thailand, the National Catastrophe Insurance Fund reinsures a portion of risks covered in catastrophe insurance policies offered by the private sector for flood, earthquake and windstorm damage. In the United States, direct flood insurance is offered through the public National Flood Insurance Program (NFIP). Premiums are generally risk-based, although with various exceptions (see Box 3.1).

Box 3.1. **US National Flood Insurance Program premiums**

The National Flood Insurance Program (NFIP) was established in 1968 to provide flood insurance coverage for residential and commercial properties in floodplains in response to the withdrawal of such coverage by private insurers. The insurance is offered only in communities that agree to a set of flood management conditions, including building standards and floodplain management standards approved by the Federal Emergency Management Agency (FEMA). As of 31 July 2015, the NFIP had over 5 million insurance policies in force providing almost USD 1.3 trillion in insurance coverage.

The majority of policyholders pay premiums based on the level of risks (approximately 80% of all policyholders) (National Academies of Sciences, Engineering, and Medicine, 2015)). These premiums are based on flood insurance rate maps (FIRMs) produced (and updated) by FEMA. Risk-based premiums are charged for structures built after the completion of the relevant FIRM for their community (FIRM's are developed and updated over time), based on the location of the insured property within the floodplain. Structures constructed after the completion of a FIRM must meet FEMA building standards in order to access insurance under the program.

Structures built before the completion of a community's FIRM ("pre-FIRM properties") generally do not meet FEMA building standards and/or were constructed without considering the base flood elevation for a 1-in-100 year flood. These properties are therefore much less protected against flood. Full risk-based premiums for such properties would be extremely expensive and therefore pre-FIRM property owners benefit from subsidised premiums - although these rates are still generally higher than rates charged on properties built after the completion of a FIRM and to FEMA building standards (the average annual subsidised premium for pre-FIRM properties was approximately USD 1 224, while the average annual premium for post-FIRM properties paying full-risk rates was approximately USD 492 (GAO, 2014)). The pre-FIRM properties with subsidised rates have accounted for a significant portion of losses over the history of the NFIP (Michel-Kerjan, 2010).

In July 2012, the *Biggert-Waters Flood Insurance Reform Act of 2012*, requiring the NFIP to immediately charge full risk-based premiums on all policies, was signed into law. However, some elements of the rate increase was repealed in March 2014 under the *Homeowner Flood Insurance Affordability Act of 2014*, which lowers the rate increases for some policies and prevents some future rate increases (see Box 4.9).

Source: National Academies of Sciences, Engineering, and Medicine, 2015; GAO, 2014; Michel-Kerjan, 2010.

In Hungary and the United Kingdom, public support for flood insurance is only offered for high-risk properties as coverage for lower risk properties is available from the private sector. In Hungary, *Wesselenyi Miklos Ar-es Belvizvedelmi Alap* provides flood insurance for residential properties in high-risk areas. In the United Kingdom, a not-for-profit reinsurance pool, Flood Re, has been established by industry to cover flood damage to high-risk residential properties (see Box 3.2). While not a public entity, Flood Re is formalised through legislation.

Box 3.2. **Coverage provided by UK Flood Re**

The insurance sector in the United Kingdom has established a flood reinsurance fund (Flood Re) to provide affordable reinsurance cover for high-risk residential properties. Flood insurance is included as an automatic extension to home insurance policies covering fire, theft, etc. Flood Re provides a reinsurance option that insurers can access to cover their flood exposure related to the residential properties that they insure. Insurers have the option to transfer the premiums (and claims liability) from eligible policies to Flood Re or retain the risk themselves. Flood Re was launched in April 2016 and will operate until 2039.

Premiums for the reinsurance coverage provided by Flood Re are set at rates that vary with the value of the property (rather than risk-level) in order to ensure that premium subsidies are targeted to lower-income households. Therefore, insurance companies seeking reinsurance from Flood Re for two properties of similar value (i.e. are part of the same Council Tax band) would pay the same amount for the reinsurance cover, even if the households face very different levels of flood risk.

Flood Re is funded by the premiums collected from insurers on reinsured policies and a levy collected from all insurers over five years based on the insurer's market share. The levy has been established based on an estimate of the existing cross-subsidy for high-risk residential properties previously included in all home insurance policies, with the aim of ensuring that the levy does not lead to a general increase in home insurance premiums. The funds are used to purchase reinsurance coverage on international markets. The industry levy and the premiums will be reviewed every five years with the aim of ensuring that Flood Re is adequately funded and that Flood Re is transitioning towards risk-reflective pricing, consistent with the longer-term objective of returning to a free market for flood insurance.

Source: Flood Re (2015).

Similar pools have been established by insurers (and formalised in legislation) to payout claims related to natural disaster losses in Norway (Norwegian Natural Perils Pool) and Romania (Insurance Pool against Natural Disasters). However, unlike the United Kingdom, these pools cover a broader set of natural perils and all properties (not just high-risk properties). In Belgium, private insurers provide coverage for natural disasters, although the government provides a guarantee to private insurers to cover losses for extreme events above a specific threshold (up to EUR 280 million per insurer and event if damage per insurer and event exceeds EUR 3 million plus 0.35 times the premium income of the insurer (Schwarze et al., 2011)).

Microinsurance

In many developing countries, insurance coverage for residential property and contents is generally not available or is only available at a cost above the willingness-to-pay (i.e. the maximum amount an individual is willing to pay for financial protection) of significant portions of the population. In these countries, microinsurance may provide a mechanism for offering some financial protection against flood risk. Such products can potentially be offered at an affordable price where payouts are relatively small and calculated based on parametric weather triggers (index insurance) rather than indemnity triggers and where efficient distribution channels are available. However, few products have thus far been able to demonstrate economic viability and/or generate significant scale and many microinsurance initiatives have been dependent on continued support from donor funding.

Microinsurance providing financial protection against multiple disaster perils is available in some countries. In India, *Afat Vimo* provides protection of up to INR 95 000 against building and contents damage, stock-in-trade, personal accident and death from various natural disaster risks, including floods. In the aftermath of Cyclone Phailin in 2013, *Afat Vimo* settled 125 claims and paid out INR 400 507 to individuals impacted by the event (Gupta and Agrawal, 2015). In the Philippines, which has the highest level of microinsurance penetration in Asia, microinsurance providers played a significant role in providing financial protection to those affected by Typhoon Haiyan (Yolanda) in 2013. Providers of calamity microinsurance coverage paid out over PHP 453 million to close to 110 000 policyholders at an average of just over PHP 4 000 per policyholder (Swiderek and Wipf, 2015). In Indonesia (Jakarta), a parametric trigger-based microinsurance product (*Asuransi Wahana Tata*) was developed to specifically provide financial protection against flood risk for vulnerable populations (Malagardis, 2015) although the product was eventually discontinued as the costs of providing coverage were beyond individuals' willingness-to-pay (Lamond and Penning-Roswell, 2014).

In Bangladesh, index-based flood insurance coverage (based on water depth and flooding duration) is provided to a local community organisation on behalf of local households, allowing for a more simplified structure for providing compensation (Swiss Re, 2015a). In Haiti, MiCRO provides index-based coverage to a microfinance institution (*Fonkoze*) and its borrowers against earthquake, wind and excess rainfall (Guy Carpenter, 2015). In Peru, an innovative approach that allows insurance payments to be made before the occurrence of a disaster has been developed. The Extreme El Niño Insurance Product, offered by *La Positiva*, a private insurance company in Peru, provides payouts that are triggered by the severe increases in sea surface temperatures that usually occur during an El Niño year and generally result in heavy precipitation and flooding. By paying out in advance of flooding, the funding allows policyholders to finance risk reduction measures to protect themselves against the potential losses associated with extreme El Niño years (OECD, 2015).

Public compensation

In most countries, public compensation and/or financial assistance is provided to households and businesses to mitigate the financial impact of flood events, particularly major events (national governments also provide compensation and financial assistance to sub-national governments in many countries – which is discussed in Chapter 5).

In countries where insurance coverage for flood risk is generally unavailable, government compensation absorbs the vast majority of private losses from flood events. In the Netherlands, where flood damages have generally been considered uninsurable, the national government provides partial compensation for flood damages. The Calamities and Compensation Act (*Wet Tegmoetkoming Schade bij Rampen en Zware Ongevallen - WTS*) allows the government to provide compensation to those impacted by freshwater flood events (compensation for saltwater flood damages is excluded from the WTS, although other compensation may be made available). The government decides on the amount of compensation available to affected households for a given event, up to the legislated aggregate of EUR 450 million. In Canada, provincial and territorial governments provide compensation and financial assistance to households that have suffered losses (generally only when the losses are uninsured). As damage from overland flooding is excluded from most residential insurance policies across Canada (coverage for sewer back-up is available in most provinces), flood losses are usually uninsured and therefore eligible for compensation under such programs.

Government compensation or financial assistance is also often provided in countries where flood insurance is available, either through pre-determined programs and funding mechanisms or on an *ad hoc* basis. In Australia, compensation and financial assistance is often available from state and territorial governments. In addition, for significant events (as defined by the national government), two payments by the national government are available to support recovery (Australian Government Disaster Recovery Payment) and lost income (Disaster Recovery Allowance). The United States federal government offers similar assistance to those that face unemployment as a result of a Presidentially-declared disaster (Disaster Unemployment Assistance). The United States also offers federal loans through the US Small Business Administration to homeowners (up to USD 200 000) and businesses (up to USD 2 million) for repair or replacement of damaged buildings. These loans are available once to all households and businesses affected by flood damages, although subsequent loans are only available if the homeowner or business has secured flood insurance coverage (GAO, 2014). The loans are provided for extended tenures with low interest rates available to those unable to otherwise secure credit (Kousky, Michel-Kerjan and Raschky, 2014).

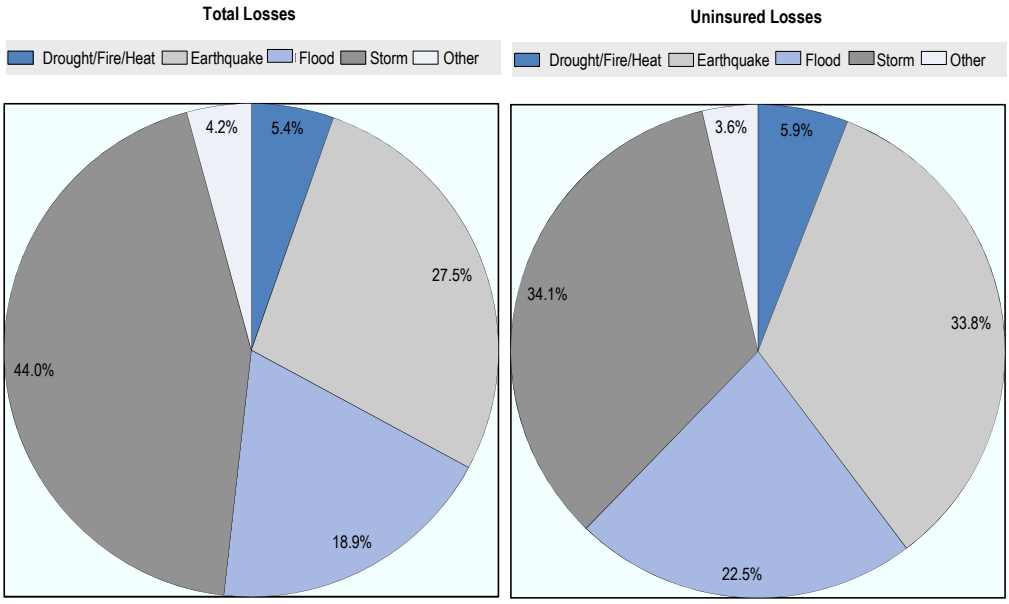
In Austria, state governments may provide compensation for flood losses to private property, a share of which can be reimbursed to state governments by the federal Austrian Catastrophes Fund. Approximately 4% of payments from the Austrian Catastrophes Fund have been used for the compensation of private losses (with the remaining 96% spent on public losses and prevention). In Belgium, the government may provide compensation and/or financial assistance to individuals affected by floods through the *Caisse nationale des Calamités* (natural disaster fund) if the compensation provided through private insurance arrangements is deemed insufficient. In Germany, there are no formal legislated requirements to provide compensation, although governments have provided compensation and financial assistance to households for damage from past major flood events. Surminski et al. (2014) found that 34 *ad hoc* compensation schemes in European Union countries for flood damage were notified to the European Commission since 2007 with a total value of EUR 1.7 billion in compensation provided.[2]

3.2 Underinsurance of flood risk

While property insurance companies, governments and micro-insurance providers offer insurance coverage against flood losses in most OECD and many other countries, significant gaps remain in terms of the share of flood losses that are covered by insurance. This is also true for many other natural disasters although there is some evidence that the gap is particularly significant for flood (as well as earthquake) losses.

While flood losses (not including losses related to storm surge, which are considered separately in statistics on disaster losses) accounted for approximately 19% of total disaster losses between 2005 and 2018, flood losses accounted for close to 23% of all uninsured losses suggesting that flood losses are less insured than other losses (see Figure 3.1).[3]

Figure 3.1. **Total and uninsured losses by disaster type**



Notes: It should be noted that the figures take account of losses insured by the National Flood Insurance Program (i.e. the share of insured losses includes losses insured by the NFIP).

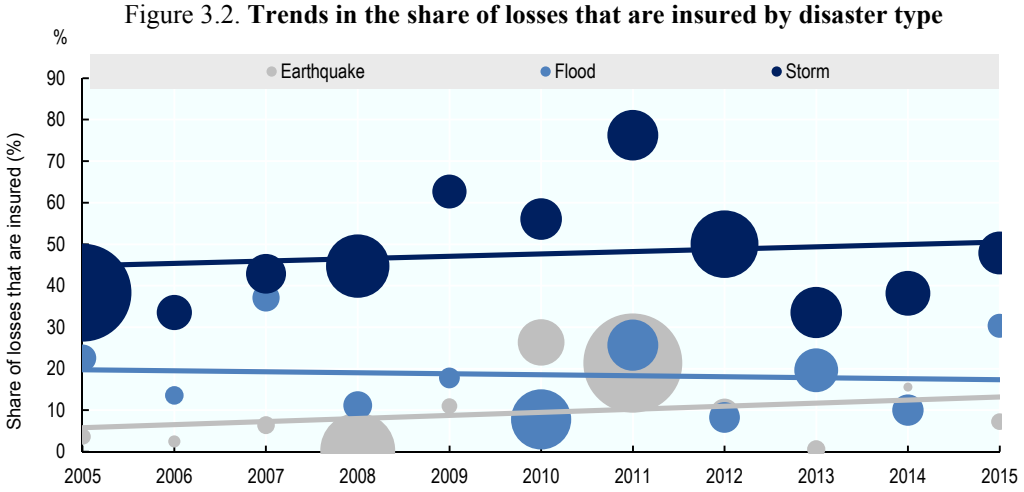
Source: OECD calculations based on insured losses and total damages reported for natural disasters (floods, storms, earthquake, droughts/fires/heat waves and other natural disasters) in Swiss Re sigma annual reports on natural and man-made catastrophes (2005-2015).

However, unlike in the case of earthquake losses (and losses from other disasters), there is also some evidence that the share of flood losses that are insured has actually declined in the past decade (although the share of losses insured can vary significantly from year-to-year). Just over 21% of losses related to flooding between 2005 and 2009 were insured relative to approximately 15% between 2010 and 2014 (see Figure 3.2).

The level of insurance penetration varies substantially across countries. In countries where flood insurance is provided as an optional add-on to residential property insurance policies, take-up rates are generally very low. For example, market penetration for the natural disaster insurance add-on in Germany is estimated at 38% despite being available to households in more than 99% of the country (GDV, 2015b). Market penetration for flood insurance coverage is also relatively low in Turkey and Austria. Estimates for other European countries, including Bulgaria, Greece, Italy and Luxemburg also found low penetration.

Requirements for flood insurance coverage attached to mortgages have led to broad coverage of flood risk in Ireland and Sweden where penetration rates are above 90% (Maccaferri, Carboni and Campolongo, 2012). However, in other countries with mortgage-related requirements for flood insurance, such as the Czech Republic and Portugal, penetration rates remain relatively low (and would likely be even lower without the mortgage-related requirements). In the United States, it is estimated that approximately 50% of all residential properties in the Special Flood Hazard Area (SFHA) are covered by flood insurance (where mortgage requirements are in place) while less than 1% of homes in the 500-year flood zone are covered (Bin and Landry, 2013).

Figure 3.2. **Trends in the share of losses that are insured by disaster type**

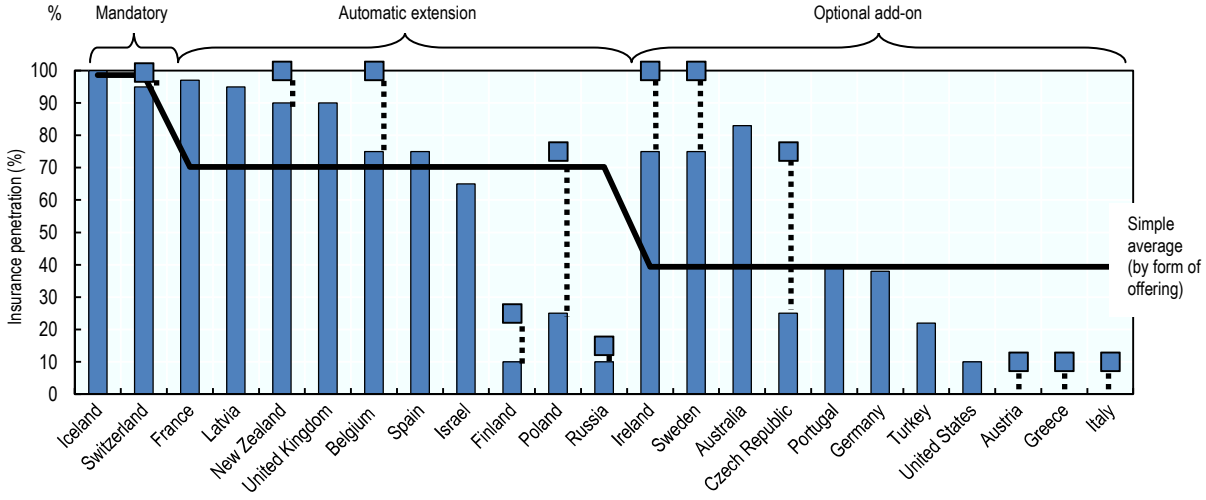


Notes: The size of the bubbles represents the magnitude of overall losses reported in that year, converted to constant 2015 USD based on the US Bureau of Labor Statistics' Historical Consumer Price Index for All Urban Consumers (CPI-U).

Source: OECD calculations based on insured losses and total losses reported for natural disasters (floods, storms, and earthquakes) in Swiss Re sigma annual reports on natural and man-made catastrophes (2005-2015).

In countries where flood risk are automatically included in standard building and contents insurance for households and businesses, penetration rates are generally higher. In the United Kingdom, take-up rates for residential property insurance are over 90% while penetration of insurance for home contents (not required by mortgage lenders), ranges from 44% to 90% (DEFRA, 2013). Penetration rates in other countries where flood risk are included in standard coverage, including Israel and Latvia, are also relatively high (see Figure 3.3).

Figure 3.3. **Estimates of residential flood insurance penetration (by form of offering)**



Notes: The dashed lines represent the range of estimated penetration rates (minimum estimate to maximum estimate). The solid line indicates the simple average across each type of offering.

Source: Most of the information on penetration rates (share of households with flood insurance coverage) was taken from country responses to an OECD questionnaire on the financial management of flood risk (2015). The estimated penetration rate for Australia is from OECD (2015); the estimated ranges for penetration rates in Belgium, Czech Republic, Finland, Greece, Ireland, Italy and Poland are from Maccaferri, Carboni and Campolongo (2012); for the UK, the estimate is from DEFRA (2013); and for Germany, the estimate is from GDV (2015b).

In developing countries, flood insurance penetration rates are even lower as a result of lower levels of insurance market development (as well as more limited capacity to pay for many households). For example, in East Asia and the Pacific, the average non-life insurance penetration rate (i.e. premiums as a share of GDP for broad non-life coverage, not just floods) is approximately 50% of the penetration rate in Europe and 35% of the penetration rate in North America (Jha and Stanton-Geddes, 2013). In Latin America, non-life penetration rates range from less than one-quarter of the United States' penetration rate in Peru and the Dominican Republic to approximately half of the United States' rate in Brazil, Colombia and Chile (Swiss Re, 2016).

3.3 Challenges to insuring flood risk

The offering of insurance coverage for a given risk is usually economically viable only where certain criteria (or "principles of insurability") are generally met (Swiss Re, 2012; Insurance Europe, 2012). These criteria include:

- Risks must be ***quantifiable***: the probability of occurrence of a given peril, its severity and its impact in terms of damage and losses, given the structural characteristics and vulnerabilities of the insured assets, must be assessable.
- A sufficiently large community with assets at risk can be established to share the risk (***mutuality***), allowing for sufficient diversification of the risk based on differences across the community in terms of risk exposure.
- Risks must occur ***randomly***: the time and location of an insured event must be unpredictable and the occurrence must be independent of the will of the insured.

The extent to which the characteristics of a given risk exposure meets these criteria (among other factors) will impact whether insurance companies can collect the amount of premiums necessary to cover the total losses of a community of insureds (along with administrative costs and returns to investors, where provided by private insurance companies). In other words, the actuarially-sound premium rates charged to policyholders must be both within their willingness-to-pay for protection and provide sufficient funds in aggregate to cover losses and other costs.

Catastrophe risks do not always meet these criteria as a number of factors lead insurance companies to charge premiums for disaster insurance coverage that is beyond the willingness-to-pay for such coverage. Among disaster risks, floods pose particular challenges in terms of insurability for a number of reasons. According to Swiss Re (2012), "no other peril defies the basic principles of insurability to the same degree."

The following sections will outline: i) factors that drive up the price for flood insurance coverage; and ii) factors that lower the willingness-to-pay of consumers. This mismatch between demand and supply has played a role in limiting the availability of flood insurance from the private sector in a number of countries that face significant potential losses from floods, including Canada, the Netherlands and the United States (GAO, 2014; Siefert et al., 2013).

Factors affecting the price of flood insurance

There are a number of factors that affect the price at which insurance companies are willing to offer coverage for a given risk, including the size of expected losses (economic

viability), the diversity of the pool of risks covered (mutuality and randomness) as well as the level of uncertainty in estimating expected losses (quantifiability).

Size of expected losses

The expected loss on an insurance policy providing coverage for a given property depends on the frequency of damaging events as well as the extent of possible damage caused by such events. Flood-prone areas are generally (particularly outside major urban areas in developed countries) not protected for events beyond a 1-in-100 year return period which is a relatively high level of frequency for an insurance loss (by comparison, the average return period for fire is 1-in-340 years (Green and Penning-Roswell, 2004)). In the United States, a property located in a flood zone has a 26% chance of being flooded over the life of a 30-year mortgage, compared with a 1% chance of suffering a fire loss (Collins and Simpson, 2007). The average claim size for flood also tends to be larger than other natural disasters. In Australia, the average claim during the Queensland inland flooding was AUD 45 374 compared to AUD 15 959 after Cyclone Yasi (wind and flood) and approximately AUD 6 000 – 8 000 for major hail and other storms (Allianz Australia Insurance Ltd., 2011).

The frequent return periods of flooding in high-risk areas and the large level of potential damage related to each flood event means that risk-based premiums become very high for high-risk properties. The actuarially-sound annual premiums for properties prone to severe flooding (more frequently than 1-in-50 years) or that might be destroyed by storm surge more than once in a hundred years would exceed 1% of the value of the property. Even if expected damage from a 1-in-50 year flood is only 25% of the value of a property, expected annual losses on that policy would still be equivalent to 0.5% of the value of the home (or 2 500 for a home with a value of 500 000).

As noted above, climate change is expected to increase both the frequency and severity of flooding which will translate into higher expected losses. A number of studies have translated the potential increase in expected losses into estimates of the resulting increase in premiums for specific risks in hazard-prone regions of the world:

- In the Netherlands, hypothetical risk-based premiums of approximately EUR 34 per year (on average) would need to increase by 93-102% in 2040 and 641-797% in 2100 (depending on demographic assumptions) in some areas in response to a 2-3 times increase in estimated flood probability between 2015 and 2040 and a 16-20 times increase in estimated flood probability by 2100 (based on a set of sea-level and river discharge scenarios in the context of climate change (Aerts and Botzen, 2011)).
- In the United Kingdom, should global temperatures rise by 4°C, the annual average insured flood loss due to increased precipitation-based inland flooding could increase by 30%, resulting in an increase to the inland flood component of insurance premiums of approximately 21% (AIR Worldwide and UK Met Office, 2009).

Risk diversification

A large pool of diversified risk (independent and randomly-occurring losses) allows insurers to spread losses over a large number of properties and mitigate the potential for a large share of the pool to be affected by losses simultaneously. Other things equal, a smaller pool, or a pool with higher dependencies across the risks covered, will lead to higher premiums required by insurers (Schwarze and Wagner, 2007).

In the case of flood risk, building a sufficiently large pool of uncorrelated risks, including both high- and low-risk properties, is a significant challenge. Despite a high-level of uncertainty in assessing and modelling flood risk (see next section), there is a general understanding of which areas are – and are not – prone to flooding which will usually lead to adverse selection where there is no requirement for holding flood coverage (i.e. those interested in purchasing insurance will likely be limited to those facing higher levels of flood risk). Communities located in a riverine or coastal flood-plain are generally affected by floods more frequently than those that are located at a distance from (or elevation above) watercourses. Furthermore, the share of properties at high-risk of flooding is relatively small in most countries (see Table 3.2) – meaning that the vast majority of households and businesses in most countries face limited risk of flooding.

Table 3.2. **Estimates of the share of properties at high-risk of flooding**

Country	Estimate
Australia	Riverine flooding: 7% of domestic houses[1] 1-in-100 year flooding: 160 000 homes[2]
Austria	Flooding (1-in-30): 150 000 exposed people[3] Flooding (1-in-100): 350 000 exposed people [3] Flooding (1-in-300): 650 000 exposed people [3]
Canada	Flooding (1-in-75): 13% of residential properties[3]
Czech Republic	Flooding (1-in-50): 9-10% of households[3]
Estonia	Flooding (1-in-50): 6 708 residents[3] Flooding (1-in-100): 9 171 residents[3]
Germany	Flooding (1-in-50 to 1-in-200): 7.9% of households [4] Flooding (1-in-50 or higher): 1.9% of households [4]
Ireland	Flooding: 300 communities identified as facing significant risk of damaging floods (based on index of hazard and consequences)[5]
Italy	Flooding and landslide (high-risk): 1.1 million residential buildings (9% of total) [9]
Latvia	Flooding (1-in-75): <1%[3]
Portugal	2% of mainland Portugal displays high or very high vulnerability[6]
Russia	7 400 settlements are located in "flood hazard areas" [3]
Spain	Flooding (1-in-100): 3.3% of population[3]
United Kingdom	Some degree of flood risk: 6 million properties (16.7%)[7] Riverine and coastal flooding (1-in-75): 560 000 properties (England and Wales)[7]
United States	Riverine flooding (1-in-100): 4.9 million housing units[8] Coastal flooding (1-in-100): 3.8 million housing units[8] Coastal flooding (1-in-100): 16.4 million residents (5% of population)[3]

Sources: [1] Allianz Australia Insurance Ltd. (2011); [2] Collins and Simpson (2007); [3] Country responses to an OECD questionnaire on the financial management of flood risk (2015); [4] GDV (2015a); [5] Office of Public Works (2012); [6] Costa et al. (2014); [7] Ramsbottom, Sayers and Panzeri (2012); [8] National Research Council (2015); [9] Swiss Re (2015b).

The difficulty in attracting low-risk households into a flood pool limits the diversity and size of the pool, and forces insurers to charge (even) higher premiums to high-risk households seeking coverage. Where flood insurance is offered as stand-alone coverage on an optional basis, there will generally be limited take-up of flood coverage from low-risk households. For example, a study in the United States found that some households outside the SFHAs (1-in-100 year risk of flooding) perceived themselves to be at no risk of flooding (GAO, 2014) – and, as noted, less than 1% of households in the 1-in-500 year flood zone are insured. A similar challenge was faced by an insurer attempting to introduce flood insurance in Winnipeg (Canada) as demand for coverage was found to be weak or non-existent in low-risk areas (Thistlethwaite and Feltmate, 2013). Some argue that this is the most important reason why flood insurance is not broadly available from the private sector in many countries (Swiss Re, 1998).

Another pressure on pricing for flood coverage is that insurers tend to respond to "accumulation risk" or "correlation risk" (i.e. the risk of facing losses across a significant share of an insured portfolio from the same event) by charging higher premiums (The Australian Government the Treasury, 2011). The tendency of flooding to impact large areas, such as a coastal or river floodplain, creates accumulation risk as a large number of losses occur simultaneously (Allianz Australia Insurance Ltd., 2011). An insurer providing coverage in a given region subject to correlated risks could therefore face a portfolio with a limited diversity of risks (i.e. a lack of mutuality). The Queensland floods in Australia in 2011, for example, led to losses across vast areas while historical floods in Australia affected even larger areas (Allianz Australia Insurance Ltd., 2011).

Uncertainty in quantification of potential exposures

The low frequency of catastrophe events, combined with frequent changes in the level of assets at risk (due to continued economic development) and the uncertain impacts of a changing climate, makes catastrophe exposure particularly difficult for insurers to quantify. The frequent/continual losses in most lines of insurance business allow for statistical probabilities to be established with more certainty, whereas catastrophe events occur only infrequently, making accurate quantification significantly more difficult. This has led to reliance on complex catastrophe modelling for the setting of premiums able to cover expected losses. Catastrophe models use information on the probability of occurrence of events of varying magnitudes, the location, structural characteristics and vulnerabilities of assets-at-risk, and the level of insurance coverage of those assets to provide insurance companies with estimates of their exposure to different types of disaster events. The estimates are presented in terms of annual average loss and probability of loss exceedance (or exceedance probability) for a range of return periods that allow insurance companies to determine a price for providing coverage.

Flood risk poses a number of modelling challenges in terms of the scope of hazard modelling required, the impact on assets-at-risk and probability of occurrence:

- *Scope of hazard modelling*: Insurance policies will generally cover damage from flooding no matter what the cause (with some exceptions). However, the potential causes of flooding are numerous requiring significant investments in modelling to assess all possible scenarios. For example, a coastal city in a river delta could face flooding damage as a result of flash flooding, riverine flooding, groundwater flooding, coastal flooding or storm surge requiring insurers to model probabilities for many different types of both meteorological and hydrological risks to estimate their exposure to floods. Also, given that almost any area is susceptible to flash floods, modelling for flood risk is necessary for large areas, not just floodplains.

- *Impact on assets-at-risk*: Accurate flood risk assessments require detailed topographical information in order to project where water will flow and how fast, information on flood protection infrastructure and drainage systems and their relative effectiveness, detailed information on land-use in order to ascertain the level of water absorption (which is complicated where land-use patterns change rapidly, such as in fast-growing urban areas), as well as substantial information on the structure and its contents. The impact of floods on assets-at-risk depends on the level of water that actually reaches (and then penetrates) a given structure from a given precipitation or storm event. For example, a given area may be protected by a structural barrier which requires assessing the level of effective protection provided by that barrier and the potential for failure (which involves significant uncertainty). How much water reaches a given asset also

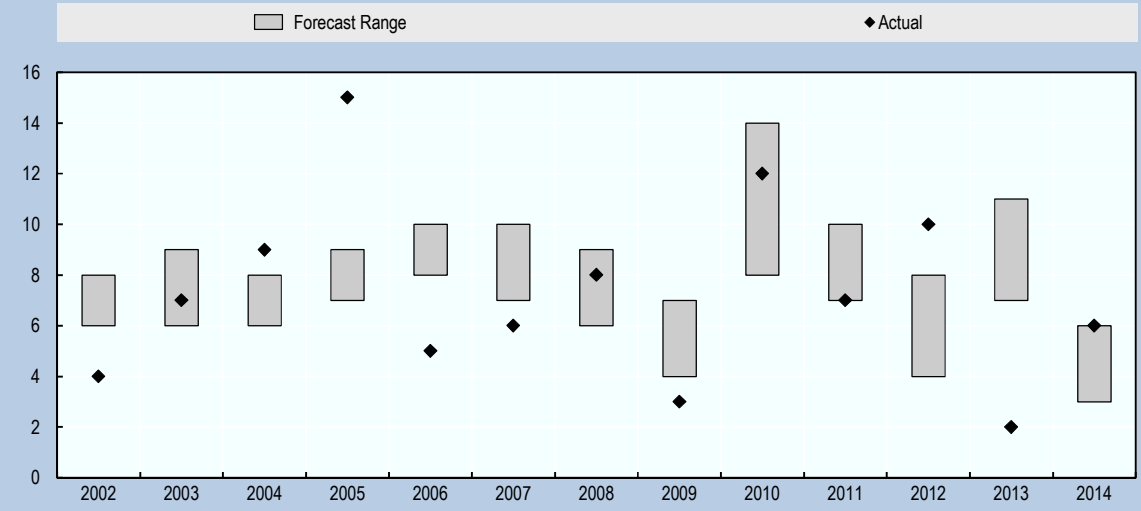
depends on the amount of water that is captured by drainage systems or absorbed in the ground, which depends on land-use, type of vegetation as well as the level of antecedent wetness in the ground. The level of water penetration into a structure and subsequent damage will depend on the type of structure (wood vs. masonry, where wood is more susceptible to flooding (Ziehmann and Hilberts, 2015)), the elevation of the structure relative to the water level as well as the location of contents (particularly, electrical installations) within the structure. Very small differences in elevation (e.g. the height of a curb) can have important implications for the depth of water reaching a given asset-at-risk.

- *Evolving probability of occurrence*: Climate change is increasing the already significant level of uncertainty involved in understanding the frequency and severity of flood events (see Box 3.3). There is uncertainty with respect to both the ultimate level of greenhouse gas emissions as well as the impact of the build-up of greenhouse gases in the atmosphere on precipitation patterns, sea-level rise and storm generation. Climate feedback loops and tipping points exacerbate these challenges and are not clearly understood (Jotzo, 2010).

Box 3.3 **Accuracy of hurricane forecasting**

North Atlantic hurricanes and tropical storms are among the most-modelled of all flood-related hazards given the significant levels of insured exposure, especially in the South-eastern United States, and the significant risk transfer that occurs for North Atlantic hurricane losses (including through international reinsurance and capital markets). However, hurricanes remain extremely difficult to predict given the number of factors that affect the generation of hurricanes including sea-surface temperatures and wind shears which are a function of periodic phenomena (such as El Niño) and the interactions between different atmospheric systems and the Atlantic ocean. On an annual basis, predictions are made on the number of hurricanes that will be generated, although given the complexity of weather systems, the level of accuracy of these forecasts is relatively low. Figure 3.4 shows the annual hurricane forecasts provided by the US National Oceanic and Atmospheric Administration (NOAA) relative to the actual number of hurricanes that were generated between 2002 and 2014.

Figure 3.4. **Annual hurricane predictions and actual hurricanes generated**



Source: Clark and Lummis (2015).

While catastrophe modelling (and continual improvements in the science (geophysics, meteorology, climatology, seismology, volcanology) behind such models) has greatly improved insurers' ability to quantify expected losses, the level of uncertainty related to expected disaster (and particularly flood) losses remains much more significant than in other lines of business (see Box 3.4). Insurance companies will tend to mitigate uncertainty in their estimates of expected losses by charging higher premiums. Research undertaken by Kunreuther et al (1995), based on a survey of underwriters, found that uncertainty in the understanding of a risk by the underwriter leads to significantly higher (1.43 to 1.77 times higher) premiums than the suggested pricing for a better understood risk. This is because an underestimation of risks can have significant implications for insurer solvency, leading insurers to account for this risk by adding an uncertainty premium. For example, Aerts and Botzen's (2011) analysis of the impact of various climate change scenarios on premiums for the coverage of flood risk in the Netherlands estimated that insurance companies would face a shortfall in reserves of almost 50% by 2030 if they wrongly set premiums in 2015 based on the expectation of a low sea-level rise scenario but were faced in reality with a high sea-level scenario (in practice, insurers would be able to increase premiums as the new scenario became evident, subject to any political or regulatory impediments to rate increases). The level of uncertainty is particularly high in developing and other countries where catastrophe models are not available (see section 4.2).

Box 3.4. **Post-event price adjustments**

The uncertainty inherent in estimating expected flood losses is evident in the significant fluctuation in insurance premiums for flood risk after flood events that seemed to have surprised the sector:

- After the Queensland floods and Cyclone Yasi in 2010-11 and subsequent floods and bushfires in 2011-12, premiums for home building insurance for some properties prone to flooding, cyclones or other natural perils in Australia increased by 400% (Douglas, Bowditch and Ni, 2013).
- The Dresden floods in Germany in 2002 led German insurers to change the basis of premium calculations to incorporate significantly higher loss-potential and shorter return periods, leading to increases in premiums of up to 60% in some flood-prone regions and the classification of large parts of the affected areas as uninsurable (or partially uninsurable, i.e. subject to a detailed evaluation of claims history and higher premiums before coverage is offered) (Schwarze and Wagner, 2007).

Source: Douglas, Bowditch and Ni, 2013; Schwarze and Wagner, 2007.

Factors affecting the willingness-to-pay for flood insurance coverage

While the level of expected losses, the limited size and diversity of risk pools and the level of uncertainty in estimating flood exposures lead to higher prices for flood insurance, a number of factors tend to reduce the demand/willingness-to-pay for flood insurance, including the tendency towards underestimation of risk, misunderstandings about coverage and expectations of post-disaster compensation or financial assistance.

As a general rule, individuals (and businesses) tend to underestimate their exposure to disaster risks which reduces their willingness-to-pay for insurance coverage. The likelihood of being impacted by a low-probability event is systematically underestimated by individuals with some controlled experiments finding many individuals unwilling to pay anything for insurance coverage against low-probability events (McClelland, Schulze and Coursey, 1993). As noted above, a general understanding of the causes of flooding (e.g. proximity to river or coast) may exacerbate the underestimation of risk among low-risk populations not obviously exposed to these customary causes of flooding. Similarly, the construction of highly-visible protective infrastructure (such as the infamous levees in New Orleans which were overtopped during Hurricane Katrina) may give communities the impression that they are no longer at risk of flooding. For example, in a survey of residents in Grand Forks (United States) after severe flooding in 1997, the second most important factor for not purchasing flood insurance was a belief that dikes and other flood control measures would provide protection (Pynn and Ljung, 1999). Policyholders also tend to allow flood insurance coverage to lapse after a few flood-free years.

Homeowners and businesses insured against fire and storm damage may not be aware of any exceptions to coverage for floods or other natural disasters. For example, in Australia, there was a general backlash against the insurance industry following the 2011 Queensland floods from homeowners that were unaware that flood damage caused by riverine flooding was not covered in their home insurance policy. The expectation of government assistance after a flood (or other disaster) event is also likely a factor in reducing demand for flood insurance, even where such assistance has been historically limited (Browne and Hoyt, 2000; Michel-Kerjan, 2010; GAO, 2014). A number of countries noted that the expectation of government compensation was a significant challenge to insurance penetration (Russia, Latvia, Turkey, Portugal, United States). A study on post-disaster grants in the United States found a statistically significant (negative) relationship between the level of post-disaster assistance for a given area and the level of insurance coverage (see Box 3.5).

Box 3.5. **The impact of financial assistance on insurance coverage in the United States**

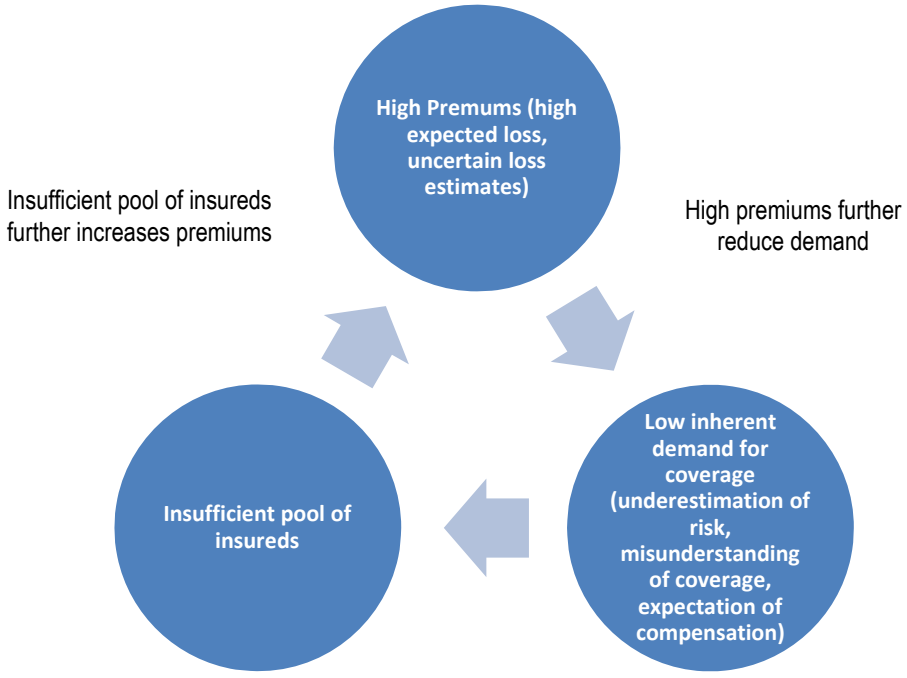
Kousky, Michel-Kerjan and Raschky (2014) examined the levels of insurance coverage in a number of US coastal regions following the occurrence of a disaster event and the provision of financial assistance to affected communities. While they found that the provision of financial assistance had a limited (or even positive) impact on decisions to insure, higher-levels of average financial assistance to a given community (based on postal codes) had a negative impact on the amount of insurance coverage chosen by households in that community - and communities that received lower average levels of financial assistance generally saw an increase in the amount of insurance coverage chosen by households. The authors concluded that insurance requirements tied to the extension of financial assistance likely had the intended impact of increasing (or at least not decreasing) the number of households that chose to purchase insurance. Low levels of financial assistance may demonstrate the need for insurance coverage while higher levels of assistance may reduce the amount of insurance coverage secured as financial assistance is seen as an alternative to insurance.

Source: Kousky, Michel-Kerjan and Raschky, 2014.

The flood insurance market failure

The combination of forces driving higher-prices and lower willingness-to-pay will often lead to a market failure in the private market for flood insurance. Low demand for flood insurance will reduce the size and diversity of the pool of risks (with limited participation from low risk households) leading to higher prices that further reduce demand (see Figure 3.5).

Figure 3.5. **Flood insurance market failure**



Low levels of insurance coverage in the event of a flood is likely to lead to greater pressure on governments to provide compensation (where such compensation is discretionary). Higher levels of government compensation is, in turn, likely to further reduce demand for insurance coverage (along with incentives for risk reduction, see next chapter). This has been termed the "disaster syndrome" (Kunreuther, 2000).

Notes

1. This requirement applies to residential and commercial properties in Special Flood Hazard Areas (SFHA). The legislative requirement for mortgage lenders to ensure that the properties they lend against are protected by public flood insurance provided by the National Flood Insurance Program is long-standing although a proposed legislative amendment ("Flood Insurance Market Parity and Modernization Act") would also allow flood insurance from private insurers to be considered as meeting this requirement.

2. For European Union member states, any aid granted by a Member State or through State resources "which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market" and must be notified to the European Commission. In general, aid "to make good the damage caused by natural disasters" is exempted from the notification requirements, as clarified through Commission Regulation No 651/2014 of 17 June 2014.

3. Earthquake losses also account for a larger portion of uninsured losses (34.7%) than would be expected based on the share of all losses caused by earthquake damage (28.4%).

References

Aerts, J., and W. Botzen (2011), "Climate change impacts on pricing long-term flood insurance: A comprehensive study for the Netherlands", *Global Environmental Change*, 21. pp. 1045-1060.

AIR Worldwide and UK Met Office (2009), "The Financial Risks of Climate Change," *ABI Research Paper No. 19*, Association of British Insurers, London.

Allianz Australia Insurance Ltd. (2011), *Natural Disaster Insurance Review Submission*, 21 July.

The Australian Government the Treasury (2011), *Natural Disaster Insurance Review: Inquiry into flood insurance and related matters (September 2011)*, Commonwealth of Australia, *www.ndir.gov.au/content/report/downloads/NDIR_final.pdf*.

Bin, O. and C. Landry (2013), "Changes in implicit flood risk premiums: Empirical evidence from the housing market", *Journal of Environmental Economics and Management*, Vol. 65, pp. 361–376.

Browne, M. and R. Hoyt (2000), "The Demand for Flood Insurance: Empirical Evidence", *Journal of Risk and Uncertainty*, Vol. 20 (3), pp. 291-306.

Clark, K. and J. Lummis (2015), *Climate Change and Hurricane Loss: Perspectives for Investors*, Karen Clark and Company, Boston, June.

Collins, E. and L. Simpson (2007), "The impact of climate change on insuring flood risks", Presented to the Institute of Actuaries of Australia Biennial Convention, 23-26 September, Christchurch, New Zealand, *http://actuaries.asn.au/Library/1.d_Conv07_Paper_Collins%20Simpson_The%20impact%20of%20climate%20change%20on%20insuring%20flood%20risk.pdf*.

Costa et al. (2014), "National Flood Vulnerability Index", *Project CIRAC - flood risk and vulnerability mapping in climate change scenarios*, *http://siam.fc.ul.pt/cirac/outputs/relatorios/Vulnerabilidade/CIRAC_Vulnerability.pdf,* accessed 20 November 2015.

DEFRA (2013), *Securing the future availability and affordability of home insurance in areas of flood risk*, UK Department for Environment, Food and Rural Affairs, London.

Douglas, J., M. Bowditch and A. Ni (2013), *Affordability of Natural Disaster Insurance*, Australian Centre for Financial Studies, *www.australiancentre.com.au/sites/default/files/NewsDocs/D1P4%20-%20Affordablity%20of%20natural%20disaster%20insurance%20Justin%20Douglas%20Treasury.pdf,* accessed 6 October 2015.

Fédération française des sociétés d'assurances (2016), *Inondations: l'indemnisation des dommages en cas de catastrophe naturelle* (website), *www.ffsa.fr/sites/jcms/c_47622/en/inondations-lindemnisation-des-dommages-en-cas-de-catastrophe-naturelle?cc=p1_1534660*, accessed 23 March 2016.

Flood Re (2015), *How it works* (website), *www.floodre.co.uk/how-it-works-overview*, accessed 12 November 2015.

GAO (2014), *Flood Insurance: Strategies for Increasing Private Sector Involvement (GAO-14-127)*, Government Accountability Office (January), Washington, DC.

GDV (2015a), *Online-Serviceteil zum Naturgefahrenreport 2015: Tabellen, Grafiken und Karten*, German Insurance Association (Gesamtverband der Deutschen Versicherungswirtschaft), GDV, Berlin, *www.gdv.de/wp-content/uploads/2015/11/GDV-Naturgefahrenreport-2015-Unwetterbilanz-Versicherer-OnlineServiceteil-n.pdf*.

GDV (2015b), *Naturgefahrenreport 2015*, German Insurance Association (Gesamtverband der Deutschen Versicherungswirtschaft), GDV, Berlin, *www.gdv.de/wp-content/uploads/2015/11/Naturgefahrenreport_2015.pdf*.

Green, C. and E. Penning-Roswell (2004), "Flood Insurance and Government: "Parasitic" and "Symbiotic" Relations", *The Geneva Papers on Risk and Insurance*, Vol. 29 (3), The Geneva Association (The International Association for the Study of Insurance Economics).

Gupta, S.S. and R. Agrawal (2015), "Micro-insurance for Disaster Management – A Case of Afat Vimo in Orissa", *Journal for Studies in Management and Planning*, Vol. 1(5).

Guy Carpenter (2015), "Flood Insurance Risk Study: Reinsurance Study", *National Flood Insurance Program: Report to Congress on Reinsuring NFIP Insurance Risk and Options for Privatizing the NFIP (13 August)*, Department of Homeland Security, Washington, DC.

Insurance Bureau of Canada (2015), *The financial management of flood risk: An international review – lessons learned from flood management programs in G8 countries*, IBC, Toronto.

Insurance Europe (2012), *Insurance Europe key points for insurers regarding natural catastrophes in Europe*, Insurance Europe, 27 November.

Jametti, M. and T. von Ungern-Sternberg (2006), "Risk selection in natural disaster insurance: the case of France", *CESIfo Working Paper No. 1683*, March.

Jha, Abhas K. and Z. Stanton-Geddes (eds.) (2013), *Strong, Safe, and Resilient: A Strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific*, World Bank, Washington, DC.

Jotzo, F. (2010), "Prerequisites and limits for economic modelling of climate change impacts and adaptation," *Environmental Economics Research Hub Research Reports*

No. 55, Environmental Economics Research Hub, Crawford School of Public Policy, The Australian National University.

Kousky, C., E. Michel-Kerjan and P. Raschky (2014), "Does Federal Assistance Crowd Out Private Demand for Insurance?", *Risk Management and Decision Processes Center Working Paper # 2014-04*, Wharton School, Philadelphia.

Kunreuther, H. (2000), "Strategies for dealing with large-scale and environmental risks", in *Frontiers in Environmental Economics*, Folmer, H. et al. (eds.), Edward Elger.

Kunreuther, H., et al. (1995), "Ambiguity and underwriter decision processes," *Journal of Economic Behavior and Organization*, Vol. 26, pp. 337-352, *http://opim.wharton.upenn.edu/risk/library/J1995_JEBO_HK_Ambiguity.pdf.*

Kunreuther, H., E. Michel-Kerjan and N. Ranger (2013), "Insuring future climate catastrophes", *Climactic Change*, Vol. 118, pp. 339-354.

Lamond, J. and E. Penning-Roswell (2014), "The robustness of flood insurance regimes given changing risk resulting from climate change", *Climate Risk Management*, Vol. 2, pp. 1–10.

Malagardis, A. (2015), "Building Institutional Capacity for the Development of Insurance Markets", Presented to the Global Seminar on Disaster Risk Financing: Towards the development of effective approaches to the financial management of disaster risks, 17-18 September, Kuala Lumpur, Malaysia, *www.oecd.org/daf/fin/insurance/global-seminar-disaster-risk-financing-2015.htm.*

Maccaferri, S., J. Carboni and F. Campolongo (2012), "Natural Catastrophes: Risk Relevance and Insurance Coverage in the EU", *EUR - Scientific and Technical Reports No. JRC67329*, Joint Research Centre, Ispra, Italy.

McClelland, G., W. Schulze and D. Coursey (1993). "Insurance for Low-Probability Hazards: A Bimodal Response to Unlikely Events", *Journal of Risk and Uncertainty*, Vol. 7, pp. 95-116.

Michel-Kerjan, E. (2010), "Catastrophe Economics: The National Flood Insurance Program", *Journal of Economic Perspectives*,Vol. 24 (4), pp. 165-186.

National Academies of Sciences, Engineering, and Medicine (2015), *A Community-Based Flood Insurance Option*, The National Academies Press,Washington, DC.

National Research Council (2015), *Affordability of National Flood Insurance Program Premiums: Report 1*, The National Academies Press, Washington, DC.

OECD (2015), *Disaster Risk Financing: A global survey of practices and challenges*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264234246-en*.

Office of Public Works (2012), *The National Preliminary Flood Risk Assessment (PFRA): Overview Report*, Office of Public Works (Ireland).

Pynn, R. and G. Ljung (1999), "Flood Insurance: A Survey of Grand Forks, North Dakota, Homeowners", *Applied Behavioral Science Review*, Vol. 7 (2), pp. 171-180.

Ramsbottom, D., P. Sayers and M. Panzeri (2012), "Climate Change Risk Assessment for the Floods and Coastal Erosion Sector", report for the UK 2012 Climate Change Risk Assessment, *http://randd.defra.gov.uk/Document.aspx?Document=CCRAfortheFloodsandCoastalErosionSector.pdf.*

Schwarze, R. et al. (2011), "Natural Hazard Insurance in Europe: Tailored Responses to Climate Change are Needed", *Environmental Policy and Governance*, Vol. 21, pp. 14-30.

Schwarze, R. and G. Wagner (2007), "The Political Economy of Natural Disaster Insurance: Lessons from the Failure of a Proposed Compulsory Insurance Scheme in Germany", *European Environment*, Vol. 17, pp. 403–415.

Seifert et al. (2013), "Influence of flood risk characteristics on flood insurance demand: a comparison between Germany and the Netherlands", *Natural Hazards and Earth Systems Science*, Vol 13, pp. 1691–1705.

Surminski et al. (2014), "Reflection on the current debate on how to link flood insurance and disaster risk reduction in the European Union", *Centre for Climate Change Economics and Policy Working Paper No. 184/ Grantham Research Institute on Climate Change and the Environment Working Paper No. 162*, Centre for Climate Change Economics and Policy, Leeds.

Swiderek, D. and J. Wipf (2015), *Aiding the disaster recovery process: The effectiveness of microinsurance service providers' response to Typhoon Haiyan*, Microinsurance Network, Luxembourg.

Swiss Re (2016), *The property protection gap in Latin America*, Swiss Reinsurance Company Ltd., Zurich.

Swiss Re (2015a), *Closing the gap: Flood protection for Bangladesh*, Swiss Reinsurance Company Ltd., Zurich.

Swiss Re (2015b), *The natural catastrophe protection gap in Italy: time for action*, Swiss Reinsurance Company Ltd., Zurich.

Swiss Re (2012), *Flood – an underestimated risk: Inspect, Inform, Insure*, Swiss Reinsurance Company Ltd., Zurich.

Swiss Re (1998), *Floods – an insurable risks*, Swiss Reinsurance Company Ltd., Zurich.

Thistlethwaite, J. and B. Feltmate (2013), *Assessing the Viability of Overland Flood Insurance: The Canadian Residential Property Market*, The Co-operators.

UNISDR (2014), *2014 Finland Peer Review − Building resilience to disasters: Implementation of the Hyogo Framework for Action (2005-2015)*, UNISDR, EC, OECD.

Wharton Risk Management and Decision Processes Center (2016), *Flood insurance around the world: Understanding residential flood insurance markets (beta version)*, *https://riskcenter.wharton.upenn.edu/flood-insurance-around-the-world/*, accessed 23 March 2016.

Wilby, R. and R. Keenan (2012), "Adapting to flood risk under climate change", *Progress in Physical Geography*, Vol. 36 (3), pp. 348–378.

Ziehmann, C. and A. Hilberts (2015), "Risk on the rise: managing inland flood risk", Webinar Presentation, 1 October, Risk Management Solutions Inc., *www.slideshare.net/RMS_News/risk-on-the-rise-managing-inland-flood-risk?mkt_tok=3RkMMJWWfF9wsRonuqjJZKXonjHpfsX%2F7uUpT%2Frn28M3109ad%2BrmPBy%2B3YIHWp8na%2BqWCgseOrQ8l14BV8S%2FRM0VrKA%3D*.