Enhancing Financial Protection Against Catastrophe Risks: The Role of Catastrophe Risk Insurance Programmes

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Foreword

The financial management of catastrophe risks presents an important public policy challenge for governments across the world. Climate change, the increasing reliance on digital technologies and socioeconomic trends such as globalisation and urbanisation are affecting the frequency and severity of the floods, cyclones, cyber-attacks and infectious disease outbreaks that produce significant financial, economic and social costs each year. In 2017, the OECD Council adopted a Recommendation on Disaster Risk Financing Strategies that provides guidance on the development of strategies for the financial management of disaster risks. The Recommendation provides a set of high-level recommendations for designing a strategy for addressing the financial impacts of disasters on individuals, businesses and sub-national levels of governments, as well as the implications for public finances.

Insurance and other forms of financial protection can make a significant contribution to reducing financial vulnerability and supporting economic recovery – although the challenges posed by risks with catastrophic potential has impeded this contribution for a number of catastrophe perils and in some countries. This report examines the role of catastrophe risk insurance programmes (i.e. loss-sharing arrangements within the insurance sector and often in partnership with governments) in broadening the availability of affordable insurance coverage for catastrophe risks and limiting risks to public finances. These programmes play a significant role in addressing some of the challenges to private sector insurability of natural catastrophe and terrorism risks in many countries – and could potentially play a role in responding to the insurability challenges for other perils such as large-scale cyber-attacks and pandemics.

This report was prepared by the OECD Insurance and Private Pensions Committee and benefited from the support and input of the OECD High-Level Advisory Board on the Financial Management of Catastrophic Risk as well as from members of the World Forum of Catastrophe Programmes and the International Forum of Terrorism Risk (Re)Insurance Programmes. The analysis also benefitted from data on economic and insured catastrophe losses provided to the OECD by Swiss Re and PCS.

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Catastrophe perils, such as floods, earthquakes and storms, cyber attacks, terrorism attacks and infectious disease outbreaks, are challenging to insure. The potential for these perils to lead to large and sometimes correlated losses as well as the complexity and relative infrequency of many types of catastrophe events often do not satisfy the traditional criteria for an "insurable risk". Exacerbated by low insurance penetration overall in some cases, there are low levels of insurance coverage for catastrophe perils in many OECD countries. While the availability of high-quality data differs across catastrophe perils, the share of catastrophe losses that go uninsured may be as high as 60% for natural catastrophe perils, 85% for cyber perils and more than 99% for business interruption losses resulting from infectious disease outbreaks. A changing climate, urbanisation, digitalisation, globalisation and other economic, social and environmental trends are likely to increase the frequency and/or severity of catastrophe events in the future, exacerbating current challenges to achieving broad levels of financial protection against catastrophe losses through insurance.

In many countries, catastrophe risk insurance programmes have been established to address some of the insurability challenges presented by catastrophe perils, particularly natural catastrophes and terrorism. The design of these programmes differs in a number of ways, including in terms of the types of insurance coverage that is offered, the scope of perils and policyholders covered, the programme's role in the larger market and the pricing structures applied in premium-setting. They also involve different levels of loss-sharing across the insurance and reinsurance sector, and with governments. These different design features have different impacts on supporting the availability and affordability of coverage, limiting public exposure to catastrophe losses and encouraging risk reduction.

Overall, catastrophe risk insurance programmes appear to have supported broader levels of insurance coverage for catastrophe perils than in countries without such programmes (particularly for earthquakes and floods). They may make a particularly significant contribution in countries where property insurance penetration levels are relatively low and where catastrophe exposure is relatively high. However, low levels of insurance coverage remain for many types of catastrophe perils in many countries. In some countries, the amount of additional premiums that would need to be collected to provide a relatively high level of protection against catastrophe risks is not insurmountable (based on historical losses). In others, the gap between insured and uninsured losses is very large and may require additional intervention to address.

Should a decision be made to support broader insurance coverage through the establishment of a catastrophe risk insurance programme, careful consideration needs to be given to the potential trade-offs inherent in different approaches to programme design:

- Approaches designed to ensure coverage availability do not always result in broad coverage as policyholders may underestimate the risk of losses or have an expectation of government financial support should a large catastrophe occur and therefore not acquire the available insurance coverage.
- Efforts to support affordability through cross-subsidisation between policyholders can blunt incentives for risk reduction and can raise issues of fairness if cross-subsidies benefit wealthier

policyholders that could afford to pay higher premiums, although some mutualisation may be necessary for some risks to become insurable.

- Subsidisation of the aggregate cost of programme coverage can put taxpayers at risk and might also raise competition concerns if the coverage provided by catastrophe risk insurance programmes competes directly with coverage provided by private insurers or reinsurers.
- Limiting the scope or amount of coverage provided by a catastrophe risk insurance programme to specific perils or policyholders can reduce public sector exposure although may lead to gaps in coverage and can also reduce the ability of the programme to benefit from diversification.
- Catastrophe risk insurance programmes can play an important role in developing modelling and risk analytics tools – particularly for perils that have not traditionally created significant exposure for private insurers or reinsurers – although limiting private sector involvement in the assumption of risk could hamper the development of private sector models and analytics.
- Catastrophe risk insurance programmes can provide a source of expertise and funding to support risk reduction although their capacity to contribute will depend on the scope of the coverage that they provide (and the amount of premiums that they collect).

Careful consideration should also be given to the differences in the characteristics of the underinsured peril. Some perils are, by nature, more challenging to quantify or lead to high levels of correlation in losses:

- Quantifying the financial consequences of infectious disease outbreaks, for example, involves uncertainties related to not only the frequency and severity of outbreaks, but also to the response of public authorities and individuals as well as the capacity of public health systems to manage the health impacts.
- A number of perils (e.g. cyber risk, infectious disease outbreaks) can materialise as both low and high severity events with not all occurrences of the peril leading to catastrophic losses.
- Perils also differ in terms of the level of correlation across countries and the diversification benefits that can be achieved in a global portfolio. Cyber risks and pandemics, for example, cannot necessarily be diversified by assuming risk in different countries.

All of these factors affect the ability of private insurance and reinsurance markets to assume risk. They will also require different approaches to the design of any catastrophe risk insurance programme established to support broader insurance coverage. For example, perils that can materialise as both high frequency low severity events and low frequency high severity events, such as cyber or infectious disease outbreaks, may be supported most effectively through reinsurance or government backstops for the highest layer of losses. Similarly, perils that do not allow for geographical diversification (e.g. pandemics) may have more limited recourse to reinsurance markets that depend on global diversification.

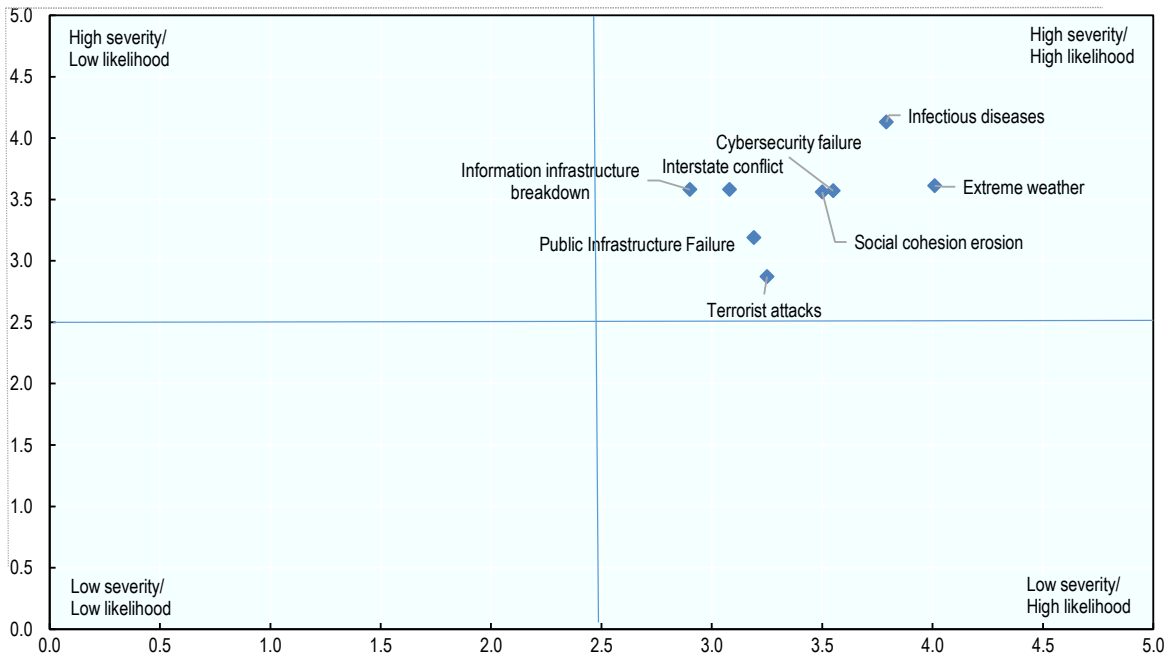
Low levels of insurance coverage of catastrophe perils can present important public policy challenges and implications for public finances if households and businesses are faced with losses that are beyond their financial capacity to absorb. If unaddressed, the occurrence of a large event could leave households and business with high levels of uninsured losses and governments with unexpected expenditure demands. Ultimately, increasing the level of insurance coverage through the establishment of catastrophe risk insurance programmes can contribute to reducing the fiscal costs of catastrophe events – and potentially at a relatively low cost given the few occasions where programmes have needed an injection of public funds. For governments, the establishment of a programme should carefully consider the potential cost and impact relative to investing directly in risk reduction as well as the relative effectiveness of responding to low levels of financial protection *ex ante* through an insurance arrangement rather than *ex post* (including any cost of setting aside capital to backstop a programme). This calculation may be different for different perils and may include some investment into both approaches.

1 Insurance coverage of catastrophe perils

One needs to look no further than the ongoing COVID-19 health crisis to recognise the enormous economic (and social) hardship that can result from large-scale catastrophes and crises. According to the OECD Economic Outlook (May 2021), global GDP across OECD declined by 3.5% in 2020 relative to a projected 3.0% increase pre-COVID (OECD, 2021[1]), (OECD, 2021[2]). The unemployment rate across OECD countries more than doubled between the first and second quarters of 2020 (5.3% to 11.4% of the labour force) and remained at 6.6% in the first quarter of 2021 despite significant government intervention in supporting employment (OECD, 2020[3]), (OECD, 2020[4]), (OECD, 2021[2]). Public debt levels (measured by debt-to-GDP ratios) in OECD countries are projected to be approximately 20% of GDP higher at the end of 2022 than they were in 2019. In many economies, government debt as a share of GDP will reach its highest level in decades (OECD, 2020[5]).

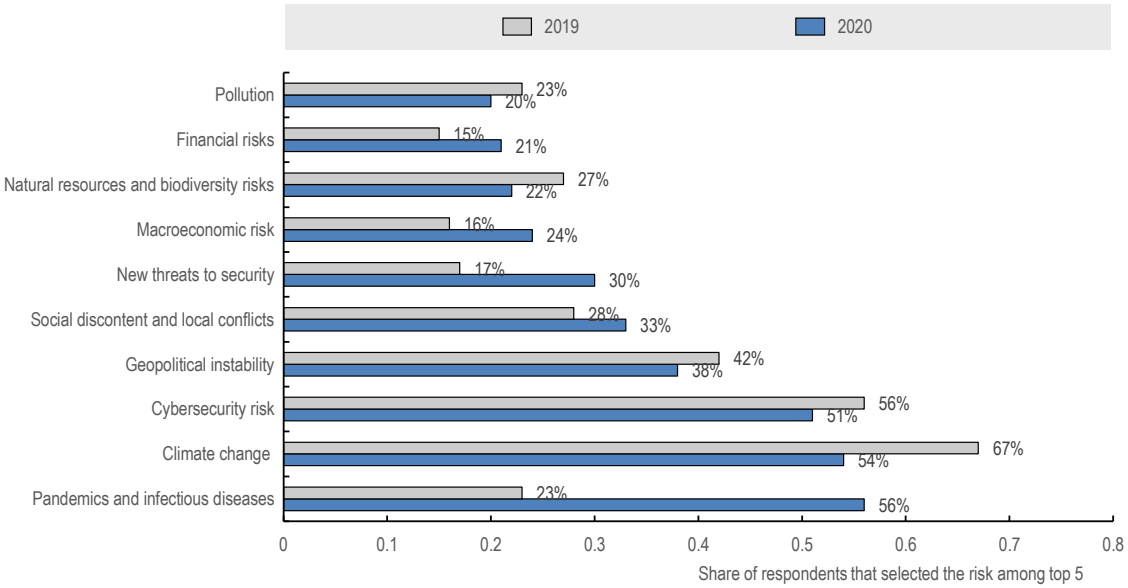
Catastrophe perils generally refer to perils that occur with lower frequency but have the potential to cause larger losses than other types of events (i.e. low frequency/high severity) (Lockett and Taylor, 1980[6]). There are a number of perils, both natural and human-made, that have the potential to result in catastrophic losses, including natural catastrophes and extreme weather events, various forms of cyber attacks, infectious diseases, infrastructure disruptions as well as social unrest, terrorist attacks and inter-state conflict. A World Economic Forum assessment of the impact and likelihood of these types of perils occurring, based on the input of risk experts from around the world, suggests that all of these perils have a higher likelihood of occurring (see Figure 1.1). A similar survey undertaken by AXA identified many of these same perils among the top five emerging risks that may have a significant impact on society, including pandemics and infectious diseases, climate change, cyber security, geopolitical instability, social discontent and local conflicts as well as new threats to security such as cyber warfare and nation state-sponsored cyber attacks and evolving terrorist attack methods (see Figure 1.2).

Figure 1.1. Severity and likelihood of catastrophe perils



Note: Survey respondents were asked to assess the likelihood of the individual global risk on a scale of 1 to 5, with 1 representing a risk that is very unlikely to happen and 5 a risk that is very likely to occur. They also assessed the impact of each global risk on a scale of 1 to 5, 1 representing a minimal impact and 5 a catastrophic impact.
Source: (World Economic Forum, 2021[7])

Figure 1.2. Top emerging risks



Source: (AXA, 2020[8])

Non-life insurance markets make an important contribution to helping policyholders (households as well as businesses) manage the risk of unexpected damages and losses resulting from the occurrence of a variety of perils. Property insurance provides financial protection to households and businesses against damage to their premises that may result from a fire and/or other perils as well as (when acquired) against the losses in revenue and additional expenses that are incurred while the damage is repaired. Cyber insurance provides businesses with financial protection against the costs and losses (as well as liability) that they may face as the result of different types of cyber incidents, such as data breaches or ransomware attacks.

A variety of studies and analyses have demonstrated the benefits of insurance coverage in terms of reducing the economic impacts of catastrophe events (specifically for natural catastrophes). Higher levels of insurance penetration or coverage have been found to reduce (Melecky and Raddatz, 2011[9]) or eliminate (in the case of full insurance) (Von Peter, Von Dahlen and Saxena, 2012[10]) contractions in economic activity after disaster events. A recent study that examined the economic implications of over 100 past disaster events found that countries with higher insurance penetration recover (on average) within 12 months whereas those with lower penetration face average recovery periods of four years (Cambridge Centre for Risk Studies and AXA XL, 2020[11]). The OECD also found a similar positive impact on post-disaster recovery from greater use of international property catastrophe reinsurance (OECD, 2018[12]). Higher insurance penetration has also been found to reduce the disaster recovery burden on taxpayers (Lloyd's, 2012[13]) and the downward pressure on sovereign credit ratings (Standard & Poor's, 2015[14]).

However, for a number of catastrophe perils (whether as a result of limited supply or limited take-up), insurance markets are not providing significant coverage, either on a global basis or in specific regions or countries. There are low levels of insurance coverage in many countries for many catastrophe perils, including natural catastrophes such as flood, storm, wildfire and earthquake as well as other potentially catastrophic perils such as cyber-attacks, political violence (including terrorism and state conflict) and infrastructure disruption. The ongoing COVID-19 health emergency has also brought to light low levels of insurance coverage for some types of losses resulting from infectious disease outbreaks.

Box 1.1. Criteria for insurability

Whether a specific "risk" (i.e. the potential for loss or damage from a specific peril to a specific insured property) is insurable depends on whether the characteristics of the risk adhere to a number of insurability criteria (Berliner, 1982[15]), (Hartwig and Gordon, 2020[16]). Some have classified these criteria into three categories (Jemli, Chtourou and Feki, 2010[17]), (Schanz, 2020[18]):

- Actuarial criteria: (i) the occurrence of the risk must be random and independent; (ii) the risk must be measurable/quantifiable (both in frequency and magnitude); (iii) losses (maximum and average) must not be too large relative to the capacity of the coverage provider; (iv) there must be a large number of independent and random risks assumed by the coverage provider; and (v) the assumption of risk should not involve significant information asymmetries, moral hazard and/or adverse selection.
- Market criteria: (i) the amount of premium that can be conceivably collected for assuming the risk is adequate; (ii) the amount of coverage provided (i.e. sum insured) is acceptable to the coverage seeker.
- Societal criteria: (i) the provision of coverage is consistent with societal values; (ii) there are no legal or public policy restrictions that impede the provision of coverage.

Some of these criteria can be perceived as fixed. For example, a risk whose occurrence is under the control of the policyholder is clearly not insurable. Other criteria may be dynamic or subjective. For example, the capacity of a coverage provider will vary over time which would impact the level of acceptable maximum loss. Similarly, the ability to quantify a risk (or a coverage provider's perception of their ability to quantify a risk) may improve over time or may differ from one coverage provider to another. In addition, a coverage provider may choose to charge a higher premium to account for any uncertainty in its ability to accurately quantify a risk which may allow the risk to be insurable (at a higher price). Some of the criteria are also clearly inter-related. For example, the willingness or capacity of coverage seekers to pay a higher premium will affect the financial capacity of the coverage provider.

As a result, some suggest that the principles for insurability should be considered as aspirational criteria against which the insurability of a specific peril should be assessed – although individual insurers and reinsurers can (and do) provide coverage for risks that do not meet all of these criteria (Berliner, 1985[19]), (Nierhaus, 1986[20]), (Schmit, 1986[21]). What may be deemed uninsurable for one coverage provider may not be for another, which creates a large "grey zone" of risks between the clearly insurable and the clearly uninsurable (Berliner, 1985[19]).

Low levels of insurance coverage of catastrophe perils may be due to a number of factors (see Box 1.1) although may ultimately result from a gap between the cost of insurance coverage and the amount that policyholders are willing to pay for such coverage:

- The lower frequency and higher severity of catastrophe events as well as higher levels of correlation of losses across policyholders can make these perils more difficult and costly to insure than other perils. There is more limited historical experience on which to base underwriting assessments leading to more pricing uncertainty. The higher severity of catastrophe events requires insurance companies to hold large reserves and/or capital to cover these losses. The potential for catastrophes to impact many policyholders simultaneously (particularly where

catastrophes can affect policyholders across different regions and sectors)[1] reduces the benefits of diversification on which the insurance business model is based.

- The lower frequency of catastrophe events may also limit the willingness of policyholders to pay for insurance coverage for catastrophe perils as the likelihood of facing losses may seem remote and/or there may be an expectation of government compensation for losses in the event of a low-likelihood catastrophic event.

Where the gap between the cost of insurance and the willingness-to-pay for that coverage is large for many or most potential policyholders – the peril may be deemed "uninsurable" by private insurance markets (or uninsurable by private markets without public involvement). Underinsured and uninsurable perils present important public policy challenges and implications for public finances. If unaddressed, the occurrence of a large (underinsured or uninsurable) event could leave households and business with high levels of uninsured losses and create political pressure for governments to provide financial support or compensation.

Insurance coverage of natural catastrophe perils

Natural catastrophe perils, including weather-related perils such as floods, storms and wildfires as well as geological perils such as earthquakes, are a significant source of insured and economic losses in many countries around the world. Between 1990 and 2019, earthquakes, floods, storms and wildfires caused an estimated USD 2.9 trillion in economic losses in OECD member countries – USD 96.5 billion on average each year.[2] There are low levels of insurance coverage for natural catastrophe perils in many OECD countries. Between 1990 and 2019, approximately 58% of economic losses from earthquakes, floods, storms and wildfires were uninsured. Levels of insurance coverage vary significantly for different perils and are lowest for earthquakes and floods. Levels of insurance coverage also vary significantly across OECD countries (see Figure1.3).

[1] An insurance company that is only active in a small geographical area or in a limited number of sectors could face correlated losses from a catastrophe affecting its region or sector of focus making it difficult for the insurance company to diversify its risk (although the insurer could cede risk to a reinsurer with a more diversified portfolio of risks). An insurance (or reinsurance) company that is active across regions or sectors would only face challenges in diversifying its risk in the context of a catastrophe event that affects multiple sectors and regions simultaneously.

[2] OECD calculations based on data provided by Swiss Re sigma. Includes all events with reported economic losses.

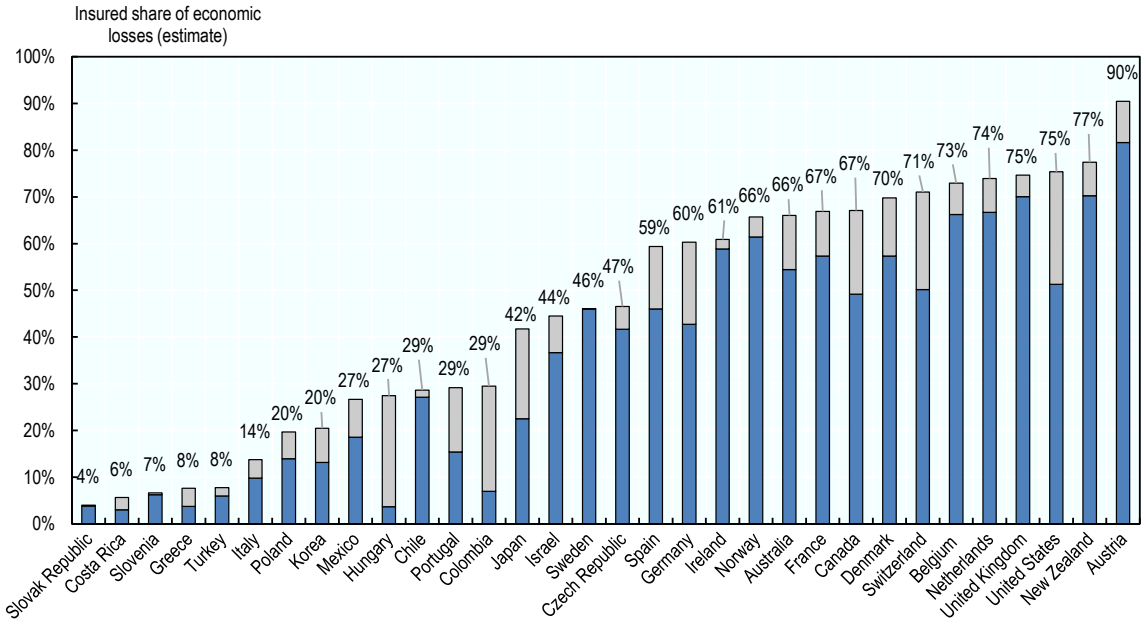
Box 1.2. Catastrophe loss data

The data on insured and economic losses used in this report was provided by Swiss Re's sigma service (insured and economic losses for most countries, natural catastrophes, terrorism and social unrest) and PCS (insured losses for selected countries, natural catastrophes, terrorism and social unrest). For some events, the data was supplemented by other sources. The data is presented in constant 2019 USD.

Swiss Re's economic loss data includes "all financial losses directly attributable to a major event", including damage to buildings, infrastructure, motor vehicles and other physical assets as well as "business interruption as a direct consequence of the property damage" (Swiss Re Institute, 2021[22]). Insured losses includes non-life insurance losses borne by both private and public insurers gross of any reinsurance, excluding liability. This data is collected from various sources including newspapers, direct insurance and reinsurance periodicals, specialist publications and reports from insurers and reinsurers (Swiss Re Institute, 2021[22]). PCS insured loss data is collected from insurance companies for designated catastrophe events in the markets where it is active and includes losses under personal property, vehicle, and commercial property lines of business (PCS, 2020[23]). The data from Swiss Re includes any event that resulted in insured losses of more than USD 52.7 million, economic losses of more than USD 105.4 million, 20 or more deaths, 50 or more injuries or 2 000 or more people made homeless. The data from PCS includes all events designated as a catastrophe by PCS which is defined as an event with insured losses of more than USD 25 million (United States), CAD 25 million (Canada), TRY 30 million (Turkey), USD 2 billion (Japan) and MXN 300 million (Mexico).

Given the thresholds that apply, the number of events included in the analysis is somewhat limited (approximately 1 300 events between 1990 and 2019 in OECD countries), particularly in smaller countries or those with more limited exposure to natural catastrophe perils. As a result, calculations of the insured share of catastrophe losses may be overly impacted by the reported data for a single event (or very few events). An over-estimation of economic losses or under-estimation of insured losses (or vice versa) could therefore have a significant impact on the data presented in this report.

Figure 1.3. Share of natural catastrophe economic losses insured by country (1990-2019)



Note: The chart shows two estimates: (i) the share of all economic losses insured (1990-2019); and (ii) the average of the insured share of losses for each individual event. The data label refers to the higher of the two estimates. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS. Includes reported economic losses only for events for which an insured loss estimate is also available.

Low levels of insurance coverage of natural catastrophe perils may be driven by a number of factors, including differences in how catastrophe insurance coverage is made available to households and businesses, uncertainty in loss estimates and the potential for high severity events. A changing climate and continued development in hazard-prone areas are likely to increase the amount of economic losses incurred as a result of natural catastrophe perils in the future. There is some evidence that economic losses for some perils have been increasing in many countries (including Japan, Portugal, Spain, Australia, Chile and Canada) while more intense cyclones and longer fire seasons (amongst other climate change impacts) could lead to even greater increases in some countries as soon as 2030. Low levels of property insurance penetration more generally in some countries also continues to be a significant driver of low levels of insurance coverage of natural catastrophe perils.

In a few countries and regions, insurability challenges are emerging for some perils as insurers increase prices - or withdraw coverage – for high-risk policyholders (e.g. fire coverage in California's wildfire-susceptible areas and hurricane coverage in Florida (United States), flood coverage in Ireland, cyclone coverage in Northern Australia). In a few countries, the share of economic losses insured between 2010 and 2019 may have declined relative to the previous two decades for some perils (e.g. floods in Australia, Mexico and Poland and storm in the United States). Others have made only limited progress in closing the gap between insured and economic losses resulting from natural catastrophe perils.

A more comprehensive overview of insurance coverage of natural catastrophe perils is provided in Annex A.

Insurance coverage of cyber risks

The digital transformation of the economy has led to new risks and new insurance coverages to protect against those risks. Cyber risk refers to the broad range of incidents - whether intentional or unintentional, malicious or accidental - that could lead to a compromise of the confidentiality, integrity and/or availability of information and information systems and result in losses to those dependent on that information and those information systems. Cyber insurance coverage has been developed to address (some) of these losses, either in a stand-alone cyber insurance policy or through expansions to the scope of coverage in other types of property/business interruption or liability policies (sometimes unintentional).

While the market has grown rapidly, there remains a significant gap between economic losses and insured losses resulting from: (i) low levels of take-up and coverage; and (ii) potentially significant gaps in coverage. While data on the cost of cyber incidents and the amount of insured cyber losses is more limited than in the case of natural catastrophe perils, the share of cyber losses that is uninsured is likely above 70% and may be as high as 85%-90% of all cyber losses incurred.

As a relatively new insurance line that has been built (in part) by replacing coverages that may have been found in other lines of business (such as property, crime and liability), the development of the cyber insurance market has faced a number of challenges related to policyholder awareness and education that has limited take-up. At the same time, challenges in quantifying loss potential and the possibility for "systemic" events affecting many policyholders simultaneously has limited the amount of coverage that insurers (and reinsurers) are willing to provide. Technological developments, such as reliance on cloud computing and the increasing use of connected operational technologies to control critical physical functions as well as the continued involvement of nation-states in generating attacks also have the potential to lead to important gaps in coverage availability. While the cyber insurance market has performed well in recent years, there is some evidence of insurability challenges related to the broad shift to work-from-home arrangements and an increasing frequency and severity in ransomware attacks in 2020 and 2021. These challenges have contributed to rising prices and may have exacerbated existing challenges in access to some types of reinsurance support.

A more comprehensive overview of insurance coverage of cyber risks is provided in Annex B.

Insurance coverage of infectious disease outbreaks

The experience of the COVID-19 health crisis – and particularly the measures taken by governments around the world to constrain the spread of the virus – has clearly demonstrated the potential for significant losses from infectious disease outbreaks across many lines of insurance. The measures put in place to slow the spread of the virus in most countries led to a significant decline in business revenues as potential customers were unwilling or unable to make purchases and many businesses were forced to close altogether in order to be compliant with government requirements.

While still subject to ongoing disputes and litigation on the application of business interruption coverage to pandemic-related business revenue losses, it is unlikely that insurance will ultimately cover a significant share of the revenue losses incurred by business. A comparison of estimates of ultimate insurance losses and business revenue losses resulting from just a single month of confinement measures suggests that the share of uninsured losses exceeds 99%. Even if policyholders are successful in claiming a broader level of coverage, it is unlikely that insurers and reinsurers will (on their own) make significant levels of insurance available for business interruption resulting from future pandemics.

The potential magnitude of business interruption losses from a global pandemic similar to COVID-19 as well as the high-level of correlation of loss occurrence across policyholders around the world create significant obstacles to providing insurance (and reinsurance) coverage for pandemic-related business

interruption. There is a high-level of uncertainty related to the potential frequency of pandemic events in the future (and concern about increased frequency as a result of globalisation, urbanisation and increasing encroachment on natural habitats). It is also unclear whether the public sector response to any future pandemic (and therefore the magnitude of resulting business losses) will be similar to the response to COVID-19.

A more comprehensive overview of insurance coverage of infectious disease outbreaks is provided in Annex C.

Insurance coverage of political violence, terrorism and social unrest

Political violence, terrorism and social unrest all have the potential to create significant property damage and business interruption losses (in addition to loss of life). Past large events, such as the September 11th terrorist attacks in the United States, as well as significant uncertainty in assessing future frequency and severity (which requires an understanding of both human motivation and the effectiveness of security measures) led to withdrawals of (re)insurance coverage for terrorism and the establishment of terrorism risk insurance programmes in many countries to support insurance availability.

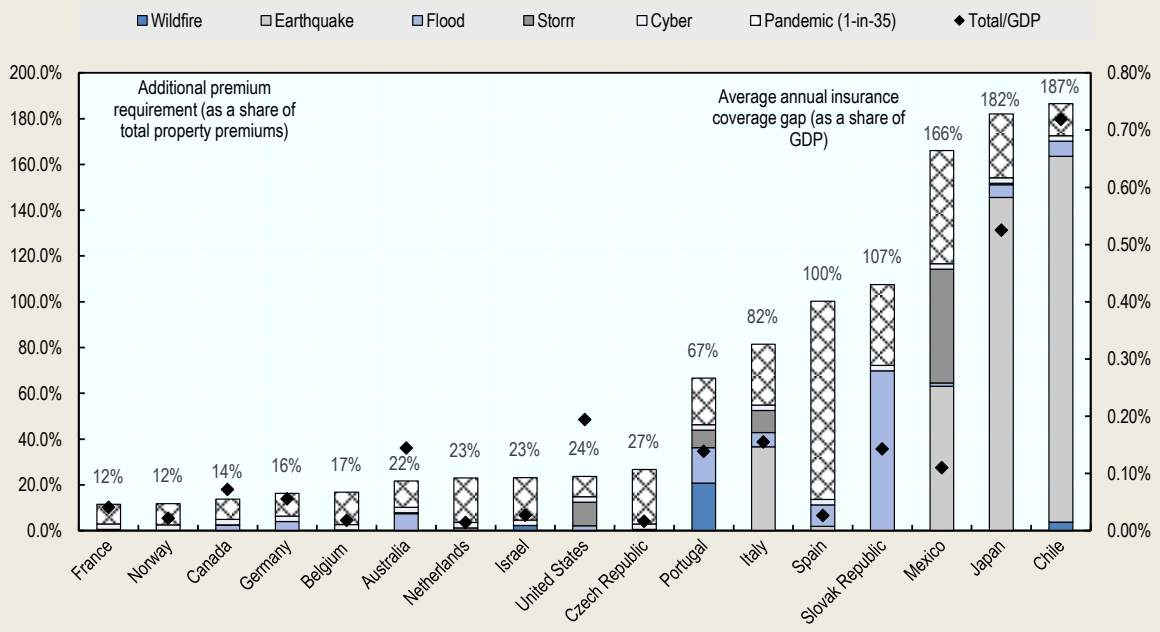
Low levels of insurance coverage for some forms of political violence, terrorism or social unrest remain in many countries. Based on the limited data available for these types of events, less than 50% of losses due to major social unrest and less than 20% of losses from terrorist attacks that have occurred since 2001 have been insured.

A more comprehensive overview of insurance coverage of political violence, terrorism and social unrest is provided in Annex D.

Box 1.3. An estimate of the cost of closing the gap between insured and economic losses

Based on OECD estimates (as described in Annexes A-D), the additional premiums that insurers would need to collect to sustainably provide "full" insurance for natural catastrophe perils, cyber risks and infectious disease outbreaks (based on historical loss levels) does not appear unattainable in most countries (although in a few countries, property insurance premium revenues would need to double or more in size).[1]

Figure 1.4. The cost of closing the gap between insured and economic losses



Note: The methodology for these estimates is outlined in annexes A-D.
Source: OECD calculations based on data sources identified in annexes A-D.

Note: [1] As outlined in the annexes, the amount of premiums that would need to be collected is calculated based on estimates of the current gap between annual economic losses and insured losses for each peril and a level of insured losses that would provide a relatively high-level of coverage for the given peril (although well below 100%.coverage of all economic losses) The calculation also incorporates a loss ratio for insurers that is based on historical experience. There is insufficient event data to include political violence perils.

The potential contribution of catastrophe risk insurance programmes

In many OECD countries, catastrophe risk insurance programmes have been established to address insurability challenges and/or low levels of insurance coverage of catastrophe perils (focused on natural catastrophes and terrorism). In many countries that have established such programmes, levels of insurance coverage for targeted perils are higher. The purpose of this report is to examine the contribution that catastrophe risk insurance programmes can make to increasing the level of insurance coverage. The following sections examine how different programme design features can support the availability and

affordability of insurance coverage for catastrophe perils while limiting public financial exposure and contributing to risk reduction. A discussion on the potential contribution that these types of programmes could make in addressing low levels of insurance coverage in other countries and for other catastrophe perils is also included.

2 Catastrophe risk insurance programmes

In many OECD countries, various types of catastrophe risk insurance programmes (see Box 2.1) have been established to support broad insurance coverage for (or, in some cases, compensate losses from) various catastrophe perils. These programmes have usually been established due to concerns about the "insurability" of the targeted peril (or perils) in private insurance markets and have often (but not always) come in response to the inability of private insurance and reinsurance markets to achieve comprehensive coverage (whether due to demand or supply issues). In many cases, these programmes have been established in the aftermath of a significant event that led to a withdrawal of insurance (or reinsurance) coverage and/or a significant increases in the cost of coverage in the impacted areas or more broadly.[3]

[3] Examples include the establishment of terrorism risk insurance programmes in many countries after the September 11th (2001) terrorist attack (and after the bombing of the Baltic Exchange in London in 1992 in the case of Pool Re) (Peters, 2020[52]), the establishment of earthquake risk insurance programmes after major earthquakes (CEA after the Northridge earthquake in California in 1994, EQC after the Wairarapa Earthquake in New Zealand in 1942, JER after the Niigata earthquake in 1964 in Japan and the TCIP after the Marmara earthquake in Turkey in 1999 (OECD, 2018[25])) and the establishment of the FHCF and the initial residual insurance market for wind cover in Florida after Hurricane Andrew in 1992 (Medders and Nicholson, 2018[35]).

Box 2.1. Catastrophe risk insurance programmes

For the purposes of this report, catastrophe risk insurance programmes include any type of arrangement established by the insurance sector and/or government to provide insurance, co-insurance, reinsurance and/or a government guarantee for losses resulting from catastrophe perils to all of specific types of potential policyholders.[1] This includes purely private sector arrangements such as the co-insurance pools established by the insurance sectors in some countries (e.g. Norsk Naturskadepool for natural catastrophe perils in Norway, Österreichischer Versicherungspool zur Deckung von Terrorrisiken (OVDT) for terrorism in Austria) and purely public arrangements such as the establishment of one or more public insurers to provide insurance coverage for catastrophe perils (e.g. the government-owned catastrophe risk insurers in Iceland, New Zealand and Spain).

It does not include government-owned insurance companies that operate in many lines of business and that have not been specifically established to cover catastrophe perils or other property-related risks nor government-owned insurers targeting other specific lines of business (such as the public insurers providing motor vehicle insurance in some Canadian provinces). The catastrophe risk insurance programmes that provide governments (rather than households or businesses) with a source of funding for emergency response and recovery[2] as well as programmes that provide coverage for catastrophe-related losses in the agricultural sector are also not included in this report.

Notes:
[1] As discussed below, it includes programmes that are the main source of coverage for all losses that result from one or more catastrophe perils as well as programmes that provide coverage to only some portion of the losses resulting from one or more catastrophe perils. It does not include insurance arrangements established for one or a few policyholders, such as captive insurance arrangements or risk retention groups.
[2] These programmes, such as CCRIF in the Caribbean and Central America, PCRIC in the Pacific Islands and SEADRIF in South East Asia, have almost exclusively been established in non-OECD countries.

The establishment of a catastrophe risk insurance programme can respond to some of the challenges that hinder the insurability of catastrophe perils:

- Catastrophe risk insurance programmes can pool the risks of many policyholders (or even all policyholders) in a given country or region in order to ***establish a large pool of independent (uncorrelated) risks***. Pooling a large share of exposure to a given peril (or set of perils) allows a programme to achieve a higher-level of diversification and reduces the potential that all or a large share of covered policyholders will face losses simultaneously.
- Catastrophe risk insurance programmes can provide insurance, co-insurance or reinsurance coverage (or a government guarantee) to ***limit the magnitude of losses*** that insurers or reinsurers might face. The programme could limit individual insurers' losses directly by: (i) providing co-insurance, reinsurance or retrocession for high-severity events; (ii) providing basic direct insurance coverage that absorbs higher frequency losses; or (iii) providing coverage to high-risk policyholders. In addition, a catastrophe risk insurance programme can play a role in investing in risk reduction and therefore contributing to a reduction in the magnitude of future losses.
- Catastrophe risk insurance programmes can play a leading role in aggregating loss data and developing risk analytics and modelling tools to support ***improved measurement of risk*** (which can also make an important contribution to risk management by governments and policyholders).

Risk pooling, loss limits and improved measurement should all contribute to lower insurance costs and therefore improved coverage affordability for policyholders. Building a more diversified portfolio of risk than individual insurance companies could achieve on their own should lower the aggregate cost of coverage. An insurance pool with a higher level of risk diversification within its portfolio should have lower economic

and (often regulatory) capital needs[4] and reinsurance costs[5] (other things equal) than the aggregate capital requirements and reinsurance costs of its individual members. In addition, exemptions from taxes (corporate and/or premium taxes) as well as the non-profit status of many catastrophe risk insurance programmes should support lower premium costs.

The design of catastrophe risk insurance programmes and the type of support provided differ in five main ways:

- The ***type of insurance coverage*** offered:
  - Some countries have programmes that provide ***direct insurance coverage*** (or compensation) to policyholders for the targeted peril(s) (Denmark (flood (compensation) and NBCR[6] terrorism (compensation)), Germany (terrorism), Iceland (natural catastrophe perils), New Zealand (certain natural catastrophe perils), Spain (natural catastrophe perils and terrorism), Switzerland (natural catastrophe perils in some cantons (public insurers for real estate)), Turkey (earthquake), United States (flood, earthquake in California and various perils (particularly wind) in many states through residual plans)). In many cases, the direct insurance is provided by a publicly-owned insurer although in some others, the coverage is provided by a private insurer with a public mandate and/or financial backing (e.g. Germany (terrorism), Turkey (earthquake)).
  - Some countries have programmes that operate as a ***co-insurance arrangement*** where participating insurers pool the premiums they collect for the targeted peril(s) and the pooled funds are used to pay claims (and often to acquire reinsurance coverage) (Austria (terrorism), Belgium (terrorism), France (terrorism), Norway (natural catastrophe perils), Switzerland (natural catastrophe perils in some cantons (private insurers)).
  - Some countries have programmes that provide ***reinsurance coverage*** for the targeted peril(s), often as an excess-of-loss coverage that absorbs losses above the insurer's deductible or retention (Australia (terrorism), Finland (terrorism), France (natural catastrophe perils and terrorism[7]), Japan (earthquake and volcanic eruption[8]), Netherlands (terrorism), Switzerland (natural catastrophes in some cantons (public insurers for real estate) and terrorism), United Kingdom (flood[9] and terrorism), United States (wind in Florida)). In Japan (earthquake and volcanic eruption) and the United States (terrorism), the programmes operate as loss sharing arrangements that are triggered once losses from a covered event exceed a designated threshold.
- The ***scope of catastrophe perils and policyholders*** covered:

[4] As an illustrative example, one assessment of the amount of capital required to protect against a 1-in-100 year hurricane affecting eight US states was found to be 45% less (USD 71 billion instead of USD 130 billion) if the states pooled their risks rather than covering the risk independently (Dumm, Johnson and Watson, 2015[261]).

[5] The cost of reinsurance tends to decline as the level of diversification increases so the cost to reinsure a single (diversified) pool of risks should be lower than the aggregate cost of reinsuring multiple (less diversified) pools of risks.

[6] Terrorist attacks that make use of nuclear, biological, chemical or radiological (NBCR) materials/weapons.

[7] In France, the public reinsurer provides reinsurance coverage to insurers for natural catastrophe perils and to the co-insurance arrangement for terrorism (GAREAT).

[8] In Japan, the reinsurance coverage provided by JER is attached to a basic earthquake insurance policy that is distributed by private insurers.

[9] In the United Kingdom, Flood Re assumes all of the flood risk for policies that are ceded to it (i.e. there is no insurer deductible or retention).

- Some programmes have been established to provide insurance, co-insurance or reinsurance coverage for a ***single peril (or very few, often related, perils)*** (Australia (terrorism), Austria (terrorism), Belgium (terrorism), Denmark (NBCR terrorism and flood (compensation), separate programmes), Finland (terrorism), France (terrorism), Germany (terrorism), Japan (earthquake, volcanic eruption, tsunami), Netherlands (terrorism), New Zealand[10] (earthquake, volcanic eruption, landslide, tsunami), Switzerland (earthquake (compensation) and terrorism, separate programmes), Turkey (earthquake, landslide, tsunami), United Kingdom (flood and terrorism, separate programmes), United States (flood, terrorism, earthquake (California), wind (some states), separate programmes).
- A few programmes provide insurance, co-insurance or reinsurance for a ***broad range of catastrophe perils*** (France (natural catastrophes and terrorism), Iceland (natural catastrophes), Spain (natural catastrophes[11] and terrorism), Switzerland (natural catastrophes)).
- A few natural catastrophe risk insurance programmes only provide coverage (whether insurance, co-insurance or reinsurance) in support of ***households*** (Japan (earthquake), New Zealand (earthquake, volcanic eruption, landslide, tsunami), Turkey (earthquake), United Kingdom (flood), United States (earthquake in California[12])).
- Many terrorism risk insurance programmes only provide coverage in support of ***businesses***[13] (Australia, France, Germany, Switzerland, United Kingdom, United States). In France and Germany, the coverage provided by the programme to commercial policyholders is (primarily) targeted at large commercial policyholders.[14]
- The other programmes provide coverage in support of ***both households and businesses***, whether for natural catastrophe perils, terrorism (or both) (Austria (terrorism), Belgium (terrorism), Denmark (NBCR terrorism and flood), Finland (terrorism), France (natural catastrophes), Iceland (natural catastrophes), Netherlands (terrorism), Norway (natural catastrophes), Spain (natural catastrophes and terrorism)[15], Switzerland (natural catastrophes), United States (flood, wind (Florida) and many residual plans)).

- *The **importance of the programme*** as coverage provider:
  - A few direct insurance programmes are the ***exclusive source of insurance coverage***[16] for the targeted peril(s) (i.e. there are no other insurers offering competing coverage) (Denmark (flood (compensation) and NBCR terrorism (compensation)), Iceland (natural catastrophes), Spain[17] (natural catastrophes and terrorism), Switzerland (natural catastrophes in some

[10] New Zealand Earthquake Commission also provides insurance coverage for damages to land from flood and storm (although not for damage to buildings).

[11] In Spain, a number of natural perils (including hail, snow, wildfire and non-cyclonic winds (below 120 km/h)) are not covered by CCS but by the private market.

[12] In California, the mandatory offer requirement for earthquake coverage (and the coverage offered by CEA) extends to non-commercial residential structures of up to four units.

[13] A number of countries have separate compensation and financial support mechanisms for bodily injury suffered by victims of terrorism and other crimes.

[14] In France, participation in the terrorism co-insurance arrangement (GAREAT) is mandatory for all large commercial risks and voluntary for smaller sums insured. In Germany, the direct insurance coverage provided by Extremus for terrorism risk is only available for large commercial policyholders.

[15] In Spain, CCS also provides coverage for bodily injury.

[16] Many of the programmes will transfer some of their risk to reinsurers or retrocessionnaires.

[17] In Spain, private insurance companies could offer competing coverage although none currently do.

cantons)). The co-insurance pool in Norway (natural catastrophes) is also the sole provider of co-insurance coverage as insurers have agreed to manage all covered natural catastrophe losses through the programme. In Switzerland, most public insurers for real estate participate in a reinsurance pool for natural catastrophe risks and in a compensation scheme for earthquake risks.

- Many of the terrorism risk insurance programmes are the ***main providers of terrorism insurance or reinsurance*** for commercial policyholders (and residential (household) policyholders when eligible) although alternative (or supplementary) coverage from private insurers and reinsurers is also available and acquired (Australia, Netherlands, Switzerland, United Kingdom, United States). The terrorism co-insurance programmes in Austria and Belgium and the reinsurance pool in the Netherlands include the vast majority of private insurers as members (although membership is voluntary) and therefore these pools are the main source of coverage for terrorism (although subject to ceilings on overall payouts as discussed below). In France, participation in the co-insurance programme for terrorism risk is mandatory in the case of large policies which means the programme is the main source of coverage for large commercial terrorism risk.
- A few programmes are ***significant providers of insurance or reinsurance coverage*** for the targeted perils although alternative or supplementary coverage is also (sometimes broadly) available from private insurers and reinsurers. Some programmes provide very basic levels of direct insurance coverage to residential (household) policyholders that can be supplemented by coverage offered by private insurers (Japan (earthquake and volcanic eruption), New Zealand (certain natural catastrophe perils), Turkey (earthquake), United States (flood, although the coverage provided by the programme is more comprehensive)). The direct insurance coverage provided by the California Earthquake Authority is available as a basic coverage or on a more comprehensive basis, depending on policyholder choice, and is an alternative to coverage offered to residential (household) policyholders by private insurers (that do not offer CEA's coverage[18]). The reinsurance coverage provided by CCR in France and by FHCF in Florida (United States) is somewhat limited[19] and can be supplemented (or replaced in the case of France) by private reinsurance coverage.
- A few programmes operate as ***residual providers of insurance or reinsurance*** coverage, by offering coverage at a premium cost that would encourage cedants to retain the risk in the case of low-risk policyholders (United Kingdom (flood)) or by requiring policyholders to demonstrate that (affordable) coverage is unavailable from private insurers (most residual insurance plans in the United States). The Finnish Terrorism Pool acts as a residual reinsurer by providing coverage when all other sources of recovery are exhausted.
- Most programmes ***transfer some portion of their risk*** to reinsurance or retrocession markets (all programmes with the exception of Denmark (flood and terrorism), Spain[20] (natural

[18] CEA participating insurers offer CEA's policy to their customers and agree not to offer alternative coverage for earthquake risk.

[19] In France, insurers can cede up to 50% of their risk to CCR or choose to retain it or transfer it to a private reinsurer. CCR's reinsurance coverage is therefore normally an alternative to private reinsurance coverage (or retention by the cedant) although an estimated 90% of the market chooses to cede risk to CCR. In Florida, all insurers must transfer a portion of their risk to the FHCF although they may choose what proportion of risk to transfer. There is an overall ceiling on FHCF's exposure which means that insurers are allocated a certain amount of coverage annually. As a result, private reinsurance is usually acquired as a supplement to FHCF coverage.

[20] There is no legal impediment that restricts CCS' ability to transfer risk to reinsurance markets although no risk is currently transferred.

catastrophes and terrorism) and United States (terrorism)[21]) which reduces their role in absorbing losses even if the coverage that they provide is the sole or main source of that coverage in the market.

- The ***premium pricing structure*** implemented by the programme:
  - Some programmes provide insurance or reinsurance coverage at a ***fixed cost based on sum insured*** (and, in some cases, type of occupancy) without taking into account the location or construction characteristics of the insured property (Iceland (natural catastrophes (direct insurance)), France (natural catastrophes (reinsurance) and terrorism (co-insurance)), New Zealand (certain natural catastrophe perils (direct insurance)), Norway (natural catastrophes (co-insurance)), Switzerland (natural catastrophes in some cantons (co-insurance arranged by private insurers)), Spain (natural catastrophes and terrorism (direct insurance))). Similarly, in Belgium and the Netherlands, the terrorism co-insurance and reinsurance pools apply premiums to participating direct insurers based on market share. In Denmark, coverage for flood and NBCR terrorism losses are funded by a charge (applied *ex post* in the case of NBCR terrorism) on insurance companies (or policyholders) that is set at a fixed rate per written policy. In the United States, payments made by the programme as co-insurance for terrorism losses above specific thresholds are recouped after the event based on surcharges imposed upon commercial policyholders (no upfront premium payment is made).
  - Some programmes apply ***simplified premium structures*** that take into account broad risk characteristics, such as location in specified hazard zones and/or type of construction (Australia (terrorism (reinsurance)), Japan (earthquake and volcanic eruption (reinsurance)), Switzerland (natural catastrophes in some cantons (direct insurance provided by public insurers for real estate)), Turkey (earthquake (direct insurance)), United Kingdom (terrorism (reinsurance)), United States (flood (direct insurance)[22])).
  - A limited number of programmes apply ***fully risk-based premiums*** that take into account the location and construction characteristics of the insured property (or portfolio of properties in the case of reinsurance coverage) as well as other underwriting factors (Germany (terrorism (direct insurance)), United States (earthquake in California (direct insurance), hurricane in Florida (reinsurance) and the residual plan arrangements (direct insurance)).
- The ***involvement of the public sector*:**
  - Some programmes are operated as public insurers or reinsurers and therefore benefit from a ***government guarantee for losses that exceed their financial capacity***, in some cases unlimited (France (natural catastrophes and terrorism), New Zealand (certain natural catastrophe perils), Spain (natural catastrophes and terrorism)) while in others subject to some form of ceiling on payments (Australia (terrorism), Iceland[23] (natural catastrophes), United States (terrorism, flood)). The Danish Storm Council is a public entity that provides compensation for flood damage without limit.

[21] The US Terrorism Risk Insurance Program is a co-insurance arrangement between insurers and the federal government that is triggered when losses exceed a threshold level. No premiums are paid to the government in advance for the co-insurance provided and no reinsurance is acquired by the government for its potential exposure.

[22] The US National Flood Insurance Program is planning to implement a new premium rating model from 1 October 2021 that will incorporate more criteria related to the characteristics of individual properties into setting premiums. Many policyholders are expected to face premium reductions although some will face an increase in premiums that will be phased in over time.

[23] NTI may benefit from an unlimited state guarantee as a public insurer although it's liability is limited to 1% of total insured value per event which provides a ceiling on the amount of government backing.

- A few programmes are operated as public entities although ***do not benefit from any explicit government backing*** (Swiss public insurers for real estate and their reinsurance and earthquake pool as well as California Earthquake Authority, Florida Hurricane Catastrophe Fund and those residual plans that operate as public insurers (e.g. Florida, Louisiana) in the United States).
- Others operate as private entities that have access to a ***government guarantee for excess losses up to a pre-determined amount*** (Belgium (terrorism), Germany (terrorism), Japan (earthquake), Netherlands (terrorism), Turkey (earthquake), United Kingdom (terrorism)). The Danish Terrorism Insurance Council operates as a special entity that provides compensation for NBCR terrorism up to DKK 15 billion.
- A few programmes are ***purely private sector arrangements with no explicit financial backing*** from the government (Austria (terrorism), Norway (natural catastrophes), United Kingdom (flood), Switzerland (natural catastrophe co-insurance pool for private insurers), United States (residual insurance arrangements)).
- Some programmes ***pay premiums or fees to government*** in exchange for the financial backing provided while others receive this support at no cost.

Table 2.1. Catastrophe risk insurance programmes

	Programme	Type of insurance offered	Type of perils covered	Types of policyholders covered	Importance as coverage provider	Premium pricing	Public sector involvement
Australia	Australian Reinsurance Pool Corporation (ARPC)	Reinsurance	Terrorism	Commercial	Main provider of coverage (reinsurance)	Simplified premium structure (hazard zone)	ARPC is a government enterprise that benefits from a government guarantee for excess losses up to a pre-determined amount
Austria	Österreichischer Versicherungspool zur Deckung von Terrorrisiken (OVDT)	Co-insurance/ Reinsurance (pool)	Terrorism	Commercial Residential (household)	Main provider of coverage (co-insurance)	Various approaches, including fixed cost (sum insured)	None
Belgium	Terrorism Reinsurance and Insurance Pool (TRIP)	Co-insurance/ Reinsurance (pool)	Terrorism	Commercial Residential (household)	Main provider of coverage (co-insurance)	Fixed cost (market share)	TRIP benefits from a government guarantee for excess losses up to a pre-determined amount
Denmark	Danish Storm Council	Direct insurance (compensation)	Storm surge and inland flood	Residential (household) Commercial	Sole provider of coverage (compensation)	Fixed cost (per policy)	The Storm Council is a public entity that provides compensation for damages funded by a fee on fire insurance policies.
	Terrorism Insurance Council	Direct insurance (compensation)	Terrorism (NBCR)	Residential (household) Commercial	Sole provider of coverage (compensation)	No up-front premium. Losses are recouped through a fixed charge applied to specific types of policies.	The Terrorism Insurance Council is a special entity that provides compensation for damages.
Finland	Finnish Terrorism Pool	Reinsurance	Terrorism	Residential (household) Commercial	Residual provider of coverage (reinsurance when all other recovery sources exhausted)		None
France	Caisse centrale de réassurance (CCR)	Reinsurance	Flood, earthquake, tsunami, landslide, mudslide, avalanche, subsidence and	Residential (household) Commercial	Significant provider of coverage (reinsurance)	Fixed cost (sum insured) (uniform additional premium rate)	CCR is a government entity backed by an unlimited government guarantee

	Programme	Type of insurance offered	Type of perils covered	Types of policyholders covered	Importance as coverage provider	Premium pricing	Public sector involvement
			high winds; terrorism				
	Gestion de l'Assurance et de la Réassurance des risques Attentats et actes de Terrorisme (GAREAT)	Co-insurance/ Reinsurance (pool)	Terrorism	Commercial	Sole provider of coverage for large risks (co-insurance)	Fixed cost (sum insured)	GAREAT's reinsurance coverage is provided by private reinsurers and CCR (government entity)
Germany	Extremus	Direct insurance	Terrorism	Commercial (large)	Main provider of coverage for large risks (direct insurance)	Risk-based pricing	Extremus is backed by a limited government guarantee
Iceland	Natural Catastrophe Insurance of Iceland (NTI)	Direct insurance	Volcanic eruptions, earthquakes, landslides, avalanches, river, costal and glacial flood	Residential (household) Commercial	Sole provider of coverage (direct insurance)	Fixed cost (sum insured)	NTI is a government entity backed by an unlimited government guarantee (although overall indemnity limits apply per event)
Japan	Japan Earthquake Reinsurance (JER)	Reinsurance	Earthquake, volcanic eruptions, tsunami	Residential (household)	Significant provider of basic coverage (reinsurance)	Simplified premium structure (hazard zone and type of construction)	Losses above certain thresholds are shared by the government and industry up to a pre-determined amount
Netherlands	Nederlandse Herverzekeringsmaatschappij voor Terrorismeschaden (NHT)	Reinsurance	Terrorism	Residential (household) Commercial	Main provider of coverage (reinsurance)	Fixed cost (market share)	NHT benefits from a government guarantee for excess losses up to a pre-determined amount
New Zealand	Earthquake Commission (EQC)	Direct insurance	Earthquake, volcanic eruptions, tsunami, landslides, storm/flood (for land only)	Residential (household)	Significant provider of basic coverage (direct insurance)	Fixed cost (sum insured)	EQC is a government entity backed by an unlimited government guarantee
Norway	Norsk Naturskadepool	Co-insurance/ Reinsurance	Flood, storm, landslide, avalanche, volcanic eruption, earthquake	Residential (household) Commercial	Sole provider of coverage (co-insurance)	Fixed cost (sum insured)	Established by legislation although no government financial support is provided.
Spain	Consorcio de Compensación de	Direct insurance	Flood, earthquake, tsunami, volcanic	Residential	Sole provider of coverage (direct	Fixed cost (sum insured)	CCS is a government entity backed by an unlimited

	Programme	Type of insurance offered	Type of perils covered	Types of policyholders covered	Importance as coverage provider	Premium pricing	Public sector involvement
	Seguros (CCS)		eruption, windstorm, terrorism, social unrest	(household) Commercial	insurance)		government guarantee (although self-financed with its own capital and reserves)
Switzerland	Kantonale Gebäudeversicherungen (19 cantons) (e.g. Grisons)[1]	Direct insurance	Flood, storm, hail, avalanche, landslide, snowpressure (as well as fire)	Residential (household) Commercial	Sole provider of coverage (direct insurance) (some cantons)	Simplified premium structure (type of construction)	Established by legislation as independent self-financed entities with their own capital and reserves
	Interkantonale Rückversicherungsverband (IRV)	Reinsurance for public insurers for real estate	Flood, storm, hail, avalanche, landslide, snowpressure (as well as fire)	Residential (household) Commercial	Sole provider of coverage (reinsurance) (some cantons)	Risk-based pricing	Established by legislation as independent self-financed entity with its own capital and reserves
	Schweizerische Pool für Erdbebendeckung (SPE)	Direct insurance (compensation)	Earthquake	Residential (household) Commercial	Sole provider of coverage (compensation)	Fixed cost (sum insured)	None
	Schweizerischer Elementarschadenpool (SVV) of the private insurance sector	Co-insurance	Flood, storm, hail, avalanche, landslide	Residential (household) Commercial	Main provider of coverage (co-insurance) (some cantons)	Fixed cost (sum insured)	None
	Terrorism Reinsurance Facility	Reinsurance	Terrorism	Commercial (large)	Main provider of coverage (reinsurance)		None
Turkey	Turkish Catastrophe Insurance Pool (TCIP)	Direct insurance	Earthquake, tsunami, landslide (and other perils triggered by earthquake)	Residential (household) (within municipal boundaries)	Significant provider of basic coverage (direct insurance)	Simplified premium structure (hazard zone and type of construction)	Limited government reinsurance for losses above TCIP's capacity
United Kingdom	Flood Re	Reinsurance	Flood	Residential (household)	Residual provider of coverage (reinsurance)	Fixed cost (based on council tax band)	Established by legislation
	Pool Re	Reinsurance	Terrorism	Commercial	Main provider of coverage (reinsurance)	Simplified premium structure (hazard zone)	Unlimited government backstop for losses above Pool Re capacity

	Programme	Type of insurance offered	Type of perils covered	Types of policyholders covered	Importance as coverage provider	Premium pricing	Public sector involvement
United States	National Flood Insurance Program (NFIP)	Direct insurance and risk management programme	Flood	Residential (household) Commercial	Significant provider of basic coverage (direct insurance)	Simplified premium structure (hazard zone and elevation with exceptions, although a new rating model is set to be implemented from October 2021)	NFIP is administered by the Federal Emergency Management Agency (a government agency) The NFIP collects premiums and has the authority to borrow from the US Treasury. NFIP has transferred part of its risk to private reinsurance companies and capital market investors
	Terrorism Risk Insurance Program (TRIP)	Co-insurance	Terrorism	Commercial	Main provider of coverage (co-insurance)	No up-front premium. Post-event assessments are applied through surcharges imposed upon commercial policyholders	Limited federal government backstop through co-insurance for losses above a defined threshold
	California Earthquake Authority	Direct insurance	Earthquake	Residential (household)	Significant provider of coverage (direct insurance)	Risk-based pricing	Established by state legislation
	Fair Access to Insurance Requirements (FAIR) Plans and Beach and Windstorm Plans (e.g. Citizens Property Insurance Corporation (Florida))[2]	Direct insurance	Wind (as well as other property insurance perils such as fire and theft in some cases)	Residential (household) Commercial	Residual provider of coverage (direct insurance)	Risk-based pricing	Some residual plans are operated as public insurers (e.g. Citizens (Florida) is a state government entity)
	Florida Hurricane Catastrophe Fund (FHCF)	Reinsurance	Wind	Residential (household) Commercial	Significant provider of basic coverage (reinsurance)	Risk-based pricing	Established by state legislation and administered by a government agency

Note: [1] There are public insurers for real estate in 19 Swiss cantons. The information provided in the table is for Gebäudeversicherung Graubündenin the canton of Grisons (as an illustrative example). [2]There are residual insurance arrangements that offer coverage for all or some property risks in many US states. Similar to Citizens in Florida, these programmes are aimed at making insurance coverage available to households that are unable to secure coverage in the private market.
Source: (OECD, 2020[24]), (OECD, 2018[25]), (OECD, 2016[26]), (IFTRIP, 2017[27]), (World Forum of Catastrophe Programmes, n.d.[28]), (Savina et al., 2020[29])

The different approaches to the design of catastrophe risk insurance programmes have different impacts in terms of addressing insurability challenges, enhancing the availability (and take-up) of affordable insurance coverage for catastrophe perils, supporting risk reduction and protecting public finances. The following sections discuss how different design features impact these important policy objectives.

Type of insurance coverage offered

A catastrophe risk insurance programme that is designed to offer direct insurance will have the most direct impact on the availability and affordability of coverage for the targeted perils as these programmes are directly responsible for making offers of coverage and pricing decisions. In most cases, programmes that provide direct insurance are either publicly-owned insurers (or compensation schemes)[24] or are subject to public mandates[25] that ensure that insurance is available to all policyholders (see Box 2.2). In addition, many of these programmes apply pricing structures that support affordability through some cross-subsidisation between low-risk and high-risk policyholders (as discussed below).[26]

Co-insurance arrangements and reinsurance programmes can make (affordable) coverage available to insurers although direct insurers will still ultimately determine whether to make coverage available to policyholders and at what cost (which will ultimately affect affordability and impact take-up levels). Many co-insurance arrangements operate in countries where the purchase of coverage for the targeted peril(s) is mandatory,[27] must be included by insurers[28] or must be offered by insurers[29] which should ensure the availability of direct insurance coverage. Similarly, some reinsurance programmes provide coverage for

[24] Including the Danish Storm Council (flood), NTI (Iceland, natural catastrophes), Earthquake Commission (New Zealand, earthquake, volcanic eruption, tsunami, landslide, storm and flood (land only)), Consorcio de Compensación de Seguros (Spain, natural catastrophes and terrorism) and the National Flood Insurance Program in the United States.

[25] In California (United States), all direct residential (household) property insurers must offer earthquake coverage to their residential policyholders although the pricing for that coverage is determined by the insurer (subject to regulatory requirements related to rate-making applicable in California). The offer may be made in any of four ways: (i) an offer of an earthquake policy written by the home insurer itself; (ii) an offer of an earthquake policy written by an affiliate of the home insurer; (iii) an offer of a policy written by agreement with a separate insurer; or (iv) if the home insurer has contracted with the CEA to become a "CEA Participating Insurer," an offer of a CEA policy.

[26] For example, in Iceland, New Zealand and Spain, pricing is set at a fixed rate based on sum insured without taking into account differences in the level of exposure of different policyholders. In the United States, premiums for flood insurance provided by the National Flood Insurance Program vary based on some risk characteristics although NFIP's pricing structure has been the subject of legislation that has led to lower premiums for some high-risk policyholders.

[27] In Belgium, coverage for terrorism risk is mandatory in some lines of business. In Switzerland, property insurance with natural catastrophe coverage is mandatory in some cantons covered by the co-insurance arrangement established by private insurers.

[28] In France, terrorism insurance coverage must be included with property insurance coverage. In Norway, coverage for natural catastrophes must be included in property insurance coverage.

[29] In the United States, insurers are required to offer coverage for terrorism risk in certain lines of business, including property insurance.

perils for which policyholders must acquire coverage[30] or for which insurers must either include coverage[31] or offer coverage.[32] The impact of co-insurance and reinsurance programmes on affordability will depend on the pricing structure for the co-insurance and reinsurance coverage as well as how losses are shared between direct insurers and the programme. If the programme applies full risk-based pricing for the risks that it assumes or if direct insurers face significant deductibles or retentions, some high-risk policyholders may face high insurance costs as direct insurers would have to collect sufficient premiums to cover a large retention and/or higher co-insurance/reinsurance premiums that reflect the higher risk. However, if the programme applies a simplified or flat premium structure and takes on a significant share of the risk (i.e. low direct insurer retentions), there would be more limited incentives for direct insurers to charge fully risk-based premiums to their policyholders and high-risk policyholders are likely to benefit from lower premiums.

[30] In Switzerland, property insurance with natural catastrophe coverage is mandatory in all cantons covered by the public insurers for real estate reinsurance pool.

[31] In Australia, a declared terrorist incident voids any terrorism exclusion that is included in a commercial property policy which has the effect of requiring that insurers include coverage for terrorism. In France, coverage for natural catastrophes and terrorism must be included with property insurance coverage.

[32] In Japan, the coverage provided by the Earthquake Insurance policy reinsured by JER must be offered to all residential (household) policyholders.

Box 2.2. Ensuring availability in the context of legal or lending requirements

In a number of countries, the establishment of a catastrophe risk insurance programme has accompanied (or potentially been driven by) legal requirements that either obligate policyholders to acquire coverage or insurers to make coverage available for the targeted peril(s):

- In Iceland and some Swiss cantons, for example, households and businesses are legally required to secure insurance coverage against most natural catastrophe perils. In Belgium and France, businesses are required to acquire terrorism insurance coverage under some lines of business.
- In New Zealand, Norway, France and Spain, insurers must automatically include coverage for some or most natural catastrophe perils in the property insurance coverage that they offer to some (or all) policyholders.
- In Japan and California (United States), insurers must offer earthquake coverage to residential (household) policyholders as an optional endorsement to their property insurance policies (or optional stand-alone policy in the case of California) although policyholders may choose to opt-out of such coverage.

In other countries (or regions), lenders (e.g. mortgage providers) require their borrowers to secure insurance coverage against some catastrophe perils, either as a common prudential practice or as a requirement imposed by the banking supervisor. For example, in the United States, households located in special flood hazard zones that have borrowed funds from a federally-regulated lender are required to have flood insurance coverage.

A mandatory purchase or offer requirement (whether imposed by a government or lender) ultimately requires that insurance be available for the perils to which the requirement applies. If private insurers are unwilling or unable to offer affordable coverage, some form of government support through a catastrophe risk insurance programme is likely to be necessary.

Programmes that provide direct insurance coverage should be able to have a more direct impact on incentivising policyholder risk reduction than co-insurance or reinsurance programmes. For example, a co-insurance or reinsurance programme that applies premium discounts for mitigation by policyholders would be dependent on cedants to pass on those discounts whereas a direct insurer can ensure that the policyholder benefits from any premium reductions for risk reduction actions taken. In practice, however, most direct insurance programmes implement flat or simplified premium structures that likely have limited impact on incentivising policyholder risk reduction (with the exception of the California Earthquake Authority and the National Flood Insurance Program in the United States – as discussed below). Direct insurance programmes might also be provided with a mandate to invest directly in policyholders risk reduction initiatives (see Box 2.3) which might be more challenging for a co-insurance or reinsurance programme to implement.[33]

[33] Some reinsurance programmes invest in risk reduction at a broader level. In France, for example, 12% of the surcharge applied to each policy for natural catastrophe risk is transferred into a fund to finance risk reduction and prevention measures. The fund was initially managed by CCR and established to support the acquisition of high-risk properties damaged by a catastrophe event although the scope of its activities (as well as the share of the premium surcharge allocated to the fund) has increased over time to include other types of investments in risk reduction. In 2021, the fund was integrated into the national budget with an expanded allocation to invest in risk reduction (from EUR 131.5 million in 2020 to EUR 205 million in 2021).

Box 2.3. Catastrophe risk insurance programme investment in risk reduction

In some countries, funding for risk reduction measures is provided directly by the catastrophe risk insurance programme:

- In Switzerland, the public insurers for real estate allocate approximately CHF 80 million annually to fund and subsidise loss mitigation efforts (both before and after a loss) in order to increase the resilience of buildings against natural perils (AECA, 2019[30]).
- The CEA (California, United States) sets aside 5% of investment income (up to USD 5 million annually) to fund mitigation efforts, including an Earthquake Brace and Bolt programme[1] that provides grants of up to USD 3 000 to secure homes to their foundations and therefore reduce vulnerability to damage from ground shaking (CEA, 2020[31]). CEA is also exploring a programme that will provide additional funding to select recipients beyond the existing grant in order to cover a higher share of the cost of retrofits.
- While separate from NFIP (United States) funds, the Federal Emergency Management Agency (which administers the NFIP) provides grants to NFIP policyholders for mitigation measures through a Flood Mitigation Assistance programme that is aimed at reducing future flood losses and NFIP claims (including for the cost of elevation, relocation and flood-proofing of utility services inputs), with a particular element focused on policyholders that have faced repetitive losses (Kousky, 2018[32]).
- Similarly, in Spain, the Ministry for the Ecological Transition and the Demographic Challenge has launched a pilot project involving EUR 3 million in funding for flood resilience initiatives in five municipalities where CCS has faced large flood claims with the amount of funding allocated to each municipality based on the relative share of past CCS losses (Gurrea-Nozaleda Merayo et al., 2021[33]).
- Flood Re (United Kingdom) is mandated to support the transition to affordable risk-based pricing for flood insurance by 2039 and is therefore involved in a number of initiatives aimed at assessing, promoting and incentivising property-level flood resilience measures.

In a few cases, catastrophe risk insurance programmes support post-event risk reduction improvements (i.e. build back better). The NFIP (United States) offers an additional coverage of up to USD 30 000 that allows policyholders with a substantially damaged property to rebuild in a way that is compliant with (updated) local flood plain management requirements (Increased Cost of Compliance Coverage) which could include building elevation, relocation, demolition or flood-proofing (Kousky, 2018[32]). In the context of the first five-year review of the Flood Re programme, Flood Re has proposed changes to the scheme to allow for their reinsurance coverage to pay costs associated with resilient improvements (i.e build back better).

Note: [1] Most CEA-sponsored mitigation programmes are generally available although there is a small mitigation programme that is limited to CEA policyholders. CEA's Earthquake Brace and Bolt programme also receives federal disaster mitigation funding to extend its reach (CEA, 2020[31]).

The scope of catastrophe perils and policyholders covered

Another important difference across catastrophe risk insurance programmes is the scope of catastrophe perils and policyholders that are covered by the programme's direct insurance, co-insurance or reinsurance.

Some programmes provide coverage for a broad scope of natural catastrophe perils[34] (as well as terrorism in the case of France and Spain)[35] while others are focused on a limited subset of perils (or a single peril or set of related perils):[36]

- The establishment of programmes to provide coverage for multiple perils may be motivated by an assumption that catastrophe perils are inherently uninsurable or by a desire to achieve some level of solidarity between policyholders in different parts of the country who face different levels of exposure to catastrophe perils. The establishment of a multiple perils programme might also be perceived as providing the most efficient solution to managing and responding to catastrophe-related losses.
- Catastrophe risk insurance programmes that focus on a limited subset of perils (or a single peril or set of related perils) have often been established in response to a specific market gap in terms of the availability or affordability of insurance coverage for the targeted peril(s).[37] Most limited/single peril programmes are focused on providing coverage for earthquake risk or terrorism risk (although there are limited/single peril programmes for flood and wind in the United States). Earthquakes and terrorist attacks are perils that may create more specific insurability challenges due to their relatively lower frequency, higher severity (particularly in the case of earthquakes) and difficulties in risk quantification (particularly in the case of terrorism).

Catastrophe risk insurance programmes also differ in terms of the types of policyholders that are eligible to access the programme's insurance, co-insurance or reinsurance coverage. Different approaches to eligibility are likely linked to differences in programme objectives. For example, some natural catastrophe risk insurance programmes limit eligibility to households[38] who may have more limited financial capacity

[34] NTI (Iceland), CCR (France), the public insurers for real estate in Switzerland and CCS (Spain) provide coverage for multiple perils with some exceptions. NTI, CCR and CCS exclude (some) storm (wind) damage – based on the assumption that private insurers have the capacity to cover these perils - although CCR and CCS provide coverage for some types of wind damage (e.g., wind speeds above a certain level or tornado).

[35] Most terrorism risk insurance programmes are focused exclusively on terrorism risk (and related perils such as cyber terrorism in a few cases), with the exception of CCS in Spain which also provides direct insurance coverage for natural catastrophe perils and CCR in France which provides reinsurance for natural catastrophe perils and terrorism risk, including to insurers participating in the GAREAT co-insurance pool.

[36] JER (Japan), EQC (New Zealand), TCIP (Turkey) and CEA (California, United States) are primarily focused on earthquake risk although all but the CEA cover losses resulting from a tsunami or fire following an earthquake (in California, coverage for fire following earthquake is found in fire insurance policies while coverage for tsunami-related damages is available as part of NFIP's flood coverage). Japan's earthquake policy also covers volcanic eruption while EQC provides coverage for volcanic eruption as well as flood and storm damage to land. The coverage provided by the Danish Storm Council (Denmark), NFIP (United States) and Flood Re (United Kingdom) is limited to flood damage (inland or coastal). Coverage provided by US beach and wind plans and FHCF (Florida, United States) is limited to wind damage.

[37] Many of the limited/single peril programmes were established in the aftermath of a specific large event in response to either a large amount of uninsured losses that materialised as a result of the event or a post-event disruption to the availability of insurance coverage.

[38] The catastrophe risk insurance programmes in Japan (earthquake and volcanic eruption), New Zealand (certain natural catastrophe perils), Turkey (earthquake), United Kingdom (flood) and California (United States, earthquake) only offer coverage to residential (household) policyholders. Some other programmes, including NFIP (United States) and many US residual insurance programmes, allow commercial policyholders to access programme coverage although commercial policies make-up only a small share of overall programme coverage. One estimate suggests that non-residential policies make-up only 5% of NFIP's portfolio (Kousky, 2018[32]). Most FAIR plans had less than 1 000

to address uninsured losses from a natural catastrophe than a business. Some terrorism risk insurance programmes limit the availability of coverage to businesses - or even large businesses in some cases[39] – as these types of policyholders may face larger loss magnitudes that may be more challenging for private insurers or reinsurers to absorb. Some programmes do not limit eligibility by type of policyholder, potentially based on an assumption that the risk is challenging to insure for both residential (household) and commercial policyholders.

Programmes that provide coverage for multiple perils and/or types of policyholders have a number of advantages:

- An insurer, co-insurance pool or reinsurer covering more perils and more policyholders should be able to build a larger pool of risks.
- An insurer, co-insurance pool or reinsurer covering multiple perils should be able to achieve a higher-level of diversification in its portfolio of risks, as long as the occurrence of the covered perils are independent and uncorrelated.
- If desired, a multiple peril insurer, co-insurance pool or reinsurer would have greater scope to cross-subsidise the cost of coverage across a broader pool of policyholders than would an insurer, co-insurance pool or reinsurer providing coverage for a single peril.
- A multiple peril insurer, co-insurance pool or reinsurer would face more limited challenges related to adverse selection among policyholders as the share of policyholders facing low risk of exposure to multiple perils (and potentially unlikely to acquire coverage where optional) would be lower than the share of policyholders facing a low risk of exposure to a single peril.
- A multiple perils insurer (in particular) would provide policyholders with a single offer of coverage for multiple catastrophe perils and reduce the need for policyholders to seek coverage under different policies or endorsements[40] which is likely to support greater take-up by policyholders.
- A multiple peril insurer, co-insurance pool or reinsurer that provides coverage to all policyholders can ensure that there are no gaps in coverage for particular perils or policyholders.
- An insurer, co-insurance pool or reinsurer covering multiple perils and a broader set of policyholders should be able to gain a broader view of a country's catastrophe exposure and therefore contribute more effectively to risk reduction efforts.

Programmes that limit the scope of perils or policyholders covered may miss important insurance coverage gaps for other perils or policyholders. For example, in California (United States), take-up of earthquake coverage among commercial policyholders (who are ineligible for CEA coverage and not covered by the mandatory offer requirement applicable to residential (household) policyholders) is estimated to be very

commercial policyholders in 2019. For those that had more than 1 000 commercial policyholders, the share of commercial policies in total policy counts was less than 10% (III, 2020[181]).

[39] The terrorism risk insurance programmes in Australia, Denmark, Germany, United Kingdom and the United States only make coverage available to commercial policyholders. In Germany, Extremus is a privately-owned insurance company that offers primary coverage for terrorism risk, but only for sums insured above EUR 25 million as private insurers are assumed to have sufficient capacity to make terrorism insurance available for lower amounts.

[40] The direct insurance coverage provided by EQC for earthquakes, volcanic eruption, tsunami, landslide and flood/storm damage to land in New Zealand is automatically included in residential property insurance policies. However, other catastrophe risk insurance programmes that provide direct insurance for a single or limited set of perils require policyholders to purchase a separate policy or endorsement to their property insurance policy (terrorism insurance coverage provided by Extremus, earthquake coverage provided by TCIP in Turkey and CEA in California (United States) and the flood insurance provided by NFIP in the United States). In Japan, policyholders must be offered coverage for earthquakes along with property/fire insurance coverage and earthquake coverage can only be acquired by households that acquire fire insurance coverage.

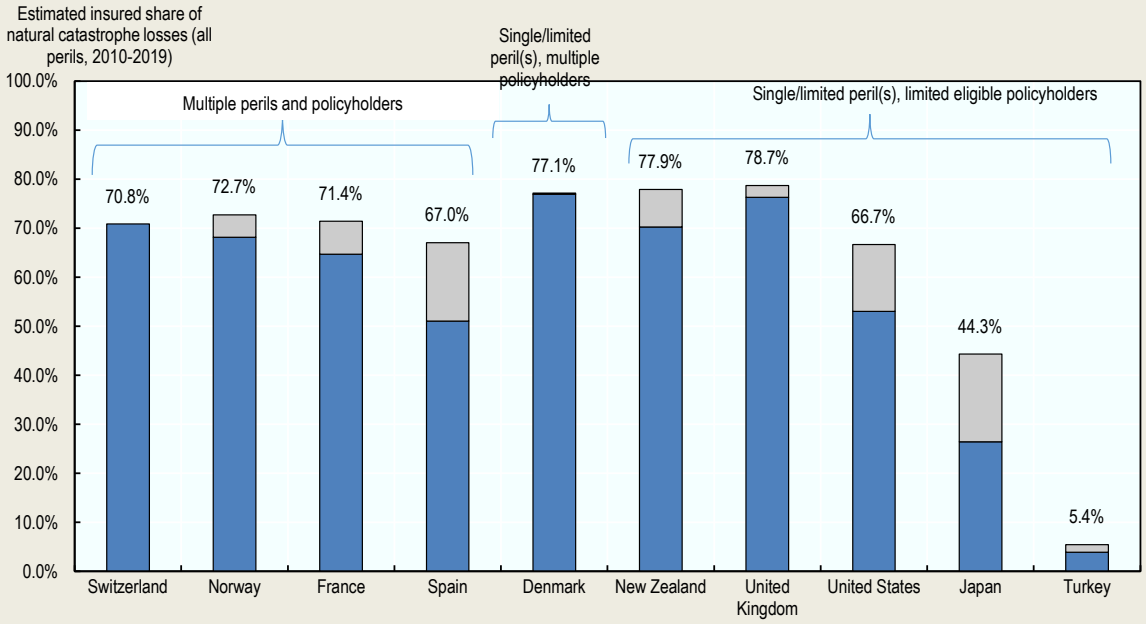
low (approximately 10%, which is lower than for residential (household) properties) (Marshall, 2018[34]). In practice, however, programmes that provide broader coverage do not always achieve lower levels of uninsured losses than programmes that are more narrowly focused on specific perils or types of policyholders (see Box 2.4).

Box 2.4. Does a broad approach to perils and policyholders reduce uninsured losses?

Programmes that provide insurance, co-insurance or reinsurance coverage for multiple perils and for both residential (household) and commercial policyholders should support a broader level of insurance coverage for catastrophe perils and reduce the share of losses that are uninsured. Figure 2.1 shows the share of natural catastrophe losses that were uninsured between 2010-2019 across countries with catastrophe risk insurance programmes that: (i) provide coverage for multiple perils and policyholders; (ii) provide coverage for a single peril for multiple policyholders; and (iii) limit coverage to a single peril (or set of perils) and a sub-set of policyholders (residential (household) policyholders only).

The countries with programmes that provide broad peril coverage to most policyholders have achieved relatively low levels of uninsured losses – although some countries with single (or limited) peril programmes (Denmark, New Zealand and the United Kingdom) have achieved even lower levels of uninsured losses. In addition, in Japan, Turkey and the United States, relatively high levels of uninsured losses were driven by the perils for which some of the catastrophe risk insurance programmes have been established (earthquake in Japan and Turkey and storm in the United States).

Figure 2.1. Insured natural catastrophe losses (2010-2019) and programme scope



Note: The chart shows two estimates: (i) the share of all economic losses insured (2010-2019); and (ii) the average of the insured share of losses for each individual event. The data label refers to the higher of the two estimates. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible. The Earthquake Commission in New Zealand is classified as a single/limited peril programme as the programme's coverage for damage to buildings is limited to earthquake, volcanic eruption, tsunami and landslide (coverage for flood and storm applies to land only). As noted above, coverage provided by the NFIP and a number of residual insurance arrangements in the United States is available to commercial policyholders although the vast majority of coverage is provided to residential (household) policyholders.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS.

Where backed by a government guarantee, multiple peril programmes and programmes that provide coverage to more types of policyholders may unnecessarily expose public finances to losses that might

otherwise be insurable in private insurance and reinsurance markets (although, as discussed below, few governments have been required to make payments on such guarantees). For example, average annual losses from floods and storms in France and from storms in Spain have been significantly lower as a share of property premiums written than many other countries where private insurance markets provide high-levels of coverage for these perils.[41] However, these programmes do protect against extreme events (i.e. events that would lead to levels of losses that are much larger than those incurred since 1990) which may not be insurable by private markets and also achieve other policy objectives, such as solidarity among policyholders across different regions. In addition, in both France and Spain, private insurance markets do provide coverage for storm (wind) damage for events with wind speeds below 120 km/h (Spain) and 145 km/h (France) and, in Spain, for direct damages from precipitation (e.g. damages to roofs from heavy rain, hail or snow).

Importance of the programme in providing coverage and absorbing losses

Catastrophe risk insurance programmes also differ in terms of the importance of the programme as insurance, co-insurance or reinsurance provider for the targeted perils and eligible policyholders and in ultimately absorbing the losses that materialise. Some programmes are the sole provider of coverage while others aim to act as residual providers mandated to address insurance gaps, particularly for high-risk policyholders. Some programmes apply limits to the amount of coverage available to policyholders individually or in aggregate which may lead to the emergence of a private market to provide alternative or supplementary coverage. Many also transfer substantial shares of the risk that they assume to private reinsurance and retrocession markets and therefore reduce the programme's ultimate exposure to losses resulting from the catastrophe perils that are covered.

Significance of the programme as coverage provider for targeted peril(s)

As noted above, in some countries, catastrophe risk insurance programmes are the sole provider of insurance, co-insurance or reinsurance for the catastrophe perils targeted by the programme, including the flood and NBCR terrorism compensation schemes in Denmark, the direct insurance programmes in Iceland, some Swiss cantons and Spain as well as the co-insurance pool for natural catastrophe in Norway and the reinsurance pool for public insurers for real estate in Switzerland. In the United States, all coverage for terrorism risk is subject to the co-insurance and backstop framework provided through the Terrorism Risk Insurance Program although policyholders may choose to acquire supplemental coverage for terrorism events that may not be certified under the Program.[42]

In other countries, the insurance, co-insurance or reinsurance available from the catastrophe risk insurance programme is made available to policyholders or cedants on a voluntary basis:

[41] Between 2010 and 2019, average annual flood economic losses in France were approximately 4.7% of property premiums written compared to close to 16% in Australia where there is no catastrophe risk insurance programme. Average annual storm economic losses in France were approximately 4.2% of property premiums written and 3.2% in Spain which compares to close to 35% in Japan, 12% in Australia and 6% in Canada where no catastrophe risk insurance programmes exist for this peril.

[42] Not unlike some other terrorism (and natural catastrophe) risk insurance programmes, a certification that the event meets the conditions and thresholds of the Terrorism Risk Insurance Program is required for the co-insurance and backstop arrangements to be implemented. Some terrorist attacks may not meet the conditions and/or thresholds and therefore would be covered (or not) based on the terms and conditions of the specific policy.

- In the case of voluntary[43] direct insurance programmes, policyholders may have the option to: (i) acquire programme coverage; (ii) acquire coverage from a private insurer; or (iii) remain uninsured. Among the direct insurance programmes that have been established for natural catastrophe and terrorism risks, only Extremus (Germany (terrorism)), the National Flood Insurance Program (United States) and the California Earthquake Authority (United States) as well as the residual insurance programmes in the United States offer coverage for risks that can also be insured by private insurers.[44] In other countries with voluntary direct insurance programmes, the policyholders can choose either to acquire programme coverage or remain uninsured.
- In the case of voluntary[45] co-insurance programmes, insurers may choose to participate in the programme, retain risk or cede risk to a reinsurer outside of the arrangement. Most of the co-insurance arrangements with voluntary participation for natural catastrophe and terrorism risks include the vast majority of insurers operating in the market (i.e. very few insurers choose not to participate in the arrangement).[46]
- In the case of voluntary[47] reinsurance programmes, the cedant may choose to acquire programme coverage, acquire reinsurance from a private reinsurer or retain the risk. The natural catastrophe and terrorism risk programmes that offer reinsurance on a voluntary basis in Australia (terrorism), France (natural catastrophes and terrorism), Netherlands (terrorism) and the United Kingdom (flood and terrorism) therefore act as alternative sources of reinsurance to private sector reinsurers. In the US state of Florida, insurers must acquire reinsurance coverage from the Florida Hurricane Catastrophe Fund although they may choose the amount of coverage acquired (and therefore the programme has both a compulsory and voluntary element).[48]

[43] As noted above, in a number of countries (or regions), the purchase of the programme's direct insurance coverage for natural catastrophe or terrorism risk is compulsory (Iceland, some Swiss cantons) or is automatically included in property insurance coverage for some or all policyholders (Denmark (flood and NBCR terrorism), New Zealand (certain natural catastrophe perils), Spain (natural catastrophes and terrorism), Turkey (earthquake, within municipal boundaries). In the United States, flood insurance coverage is mandatory for households with a federally-backed mortgage residing in a flood zone, although it can be acquired from the National Flood Insurance Program or a private insurer.

[44] In Germany, businesses seeking coverage for terrorism risk (for insured sums above EUR 25 million) can acquire coverage from Extremus or from any willing private insurer. Similarly, households (and businesses in the case of flood insurance) in the United States can acquire flood insurance coverage from the National Flood Insurance Programme or a private insurer and earthquake coverage (in California) from the California Earthquake Authority or a private insurer.

[45] Insurers in Norway are required to participate in the co-insurance arrangement for natural catastrophe risks. In France, insurers must participate in the co-insurance arrangement for terrorism risk for policies with sums insured above EUR 20 million. GAREAT's market share across small and medium-sized risks (sums insured below EUR 20 million) is only 12% (Peters, 2020[52]) indicating that the private market is providing this coverage for most policyholders without GAREAT co-insurance (or CCR reinsurance).

[46] For example, in Austria and Belgium, the vast majority of insurers (over 95%) have chosen to participate in the terrorism co-insurance pool (Peters, 2020[52]).

[47] Insurers in Japan that provide coverage for earthquake and volcanic eruption are required to cede their risk to JER (which then co-insures that risk with private insurers and the government). In the US state of Florida, all insurers must acquire reinsurance coverage from the Florida Hurricane Catastrophe Fund although they may choose the amount of coverage acquired. Similarly, the Swiss public insurers for real estate have agreed to acquire reinsurance from IRV although may choose the amount of coverage that they acquire.

[48] In Florida, insurers may choose a coverage percentage of 45%, 75% or 90%.

In some countries where insurance or reinsurance is available from both a programme and a private insurer or reinsurer, some conditions are imposed (or practices are implemented) that aim to ensure that the voluntary programme acts as a residual market for policyholders (or cedants) that have difficulty acquiring insurance or reinsurance coverage in private markets. For example, the coverage provided by the US National Flood Insurance Program has lower limits and more limited coverage for some types of losses than the flood insurance coverage available in private markets[49] (as discussed below, a number of other programmes also apply indemnity limits although, unlike in the case of the NFIP, private insurance does not tend to be an alternative to the basic coverage provided by those programmes). Regulatory changes have also been made to ensure that private flood insurance coverage is considered equivalent by mortgage lenders in the context of adhering to requirements for flood insurance coverage in special flood hazard zones (Kousky, 2018[32]).[50] In France, the reinsurance coverage provided by CCR for natural catastrophe risks is provided as a quota-share coverage for 50% of the sum insured with an unlimited stop-loss coverage for amounts above an insurer deductible. Insurers (cedants) may choose to retain all of the risk, transfer risk only to private reinsurers or seek (supplementary or alternative) reinsurance coverage from private markets although, in practice, the vast majority of insurers choose to cede their risk to CCR.[51] In the United Kingdom, Flood Re's reinsurance coverage is priced at a rate that is meant to discourage the transfer of lower-risk property policies to Flood Re while also supporting a reduced cost of reinsurance for high-risk properties. In the United States, the residual markets (FAIR plans, Beach and Wind plans as well as publicly-owned residual insurers in Florida and Louisiana) that provide households and businesses with coverage for some property risks (including wind but not flood or earthquake) often require that policyholders demonstrate their inability to acquire (affordable) coverage from private insurers before offering coverage through the residual market.[52] Many also have annual "depopulation" initiatives aimed at returning policyholders covered by the programmes to the private market.

Some residual programmes limit their role in the market by ensuring that their premiums are generally more expensive than coverage (for lower risk policyholders) in the private market. This approach can provide the flexibility needed to ensure that only policyholders that have challenges accessing affordable coverage in private markets acquire programme coverage. However, higher prices also mean reduced affordability for those policyholders that need to access the programme.

As in the case of programmes that provide broad coverage for multiple perils and types of policyholders, programmes that are more significant providers of coverage in the market can establish larger risk pools, achieve higher levels of diversification and have greater scope for cross-subsidisation relative to programmes that play a more limited role in the market. In addition, programmes that aim to act as residual markets will, by definition, be faced with a portfolio of higher risk policyholders which will likely lead to

[49] Private insurers tend to focus on offering coverage for higher-value homes and for homes located in specific areas where NFIP's pricing structure leads to premiums that may be higher than the level of risk would dictate (Kousky, 2018[32]). A non-compete clause applicable to insurers participating in the NFIP's Write-Your-Own distribution programme was eliminated in 2018 (Grzadkowska, 2018[295]) which now allows participating insurers to offer their own competing flood insurance coverage or NFIP coverage.

[50] Another legislative proposal aims at allowing policyholders to maintain access to any applicable grandfathered premium rates for NFIP coverage even if they choose to insure with a private insurer for a period of time (as long as some flood coverage is maintained on a continuous basis) (Kousky, 2018[32]).

[51] In many countries, direct insurers normally retain more than 50% of the risk that they assume so the CCR coverage may provide insurers with a similar amount of reinsurance coverage to what they would normally seek from a private reinsurer (particularly given that the CCR coverage includes a stop-loss coverage).

[52] For example, policyholders can only acquire coverage from Citizens (Florida) if coverage is not available from a Florida-authorized insurance company or if the premiums for coverage from Florida-authorized insurance companies are more than 15% percent higher than the premiums for comparable coverage from Citizens (Citizens, 2021[308]).

higher premium requirements (unless subsidised) and larger losses. For example, depopulation by Florida Citizens (i.e. transfer of lower risk policies to private insurers) has reportedly led to a requirement to increase rates more quickly for remaining higher-risk policyholders as the result of a declining premium base (Medders and Nicholson, 2018[35]). A few voluntary reinsurance programmes limit the potential for this type of adverse selection by cedants by requiring cedants to transfer either all or none of their exposure to the targeted peril to the programme.[53]

Programmes that offer voluntary or residual coverage (especially if at a higher cost) should reduce the risk that the programme is assuming risks that might otherwise be insurable in private insurance and reinsurance markets. However, where programmes offer coverage that is similar to – and can be substituted by – private insurance or reinsurance market coverage, there is a risk of creating a competitive advantage for programme coverage – particularly if the programme benefits from some form of government-backing. Among direct insurers, NFIP (United States) and Extremus (Germany) benefit from government-backing. In the case of NFIP, the government support is provided as a borrowing authority which must (normally) be repaid.[54] Extremus (Germany) makes payments to the government for the support provided. CEA (California, United States) does not benefit from government support (although it does operate as a non-profit insurer and benefits from some tax exemptions). Among reinsurers, ARPC (Australia), CCR (France), NHT (Netherlands) and Pool Re (United Kingdom) benefit from government support and pay a fee for that support (as discussed in greater detail below).

As in the case of programmes that support multiple perils and policyholders, programmes that operate as the sole or main provider of coverage will benefit from a broader view of a country's exposure to catastrophe risk and can leverage that understanding to support risk reduction. However, where a programme acts as the sole provider of coverage (and particularly where the programme retains most of the risk), there may be little incentive for the development of risk analytics by private sector service providers such as catastrophe modelling firms (see Box 2.5).

[53] ARPC (Australia) and Pool Re (United Kingdom) require cedants to cede all polices that include coverage for terrorism risk to the programmes (AXA XL, 2018[296]).

[54] In the past, some NFIP debts to the US Treasury have been forgiven. In October 2017, USD 16 billion of NFIP's debt to the US Treasury was cancelled to provide the programme with funds to pay claims related to Hurricanes Harvey, Irma and Maria (Horn, 2020[63]).

Box 2.5. Catastrophe model coverage in countries with broad programmes

One of the most important contributions of insurance to risk management has been the development of risk analytics tools such as catastrophe models to quantify the risk at the level of individual properties. Catastrophe models apply catalogues of potential hazard events (past and hypothetical) to building and infrastructure inventories and take into account their construction characteristics and structural vulnerabilities to develop probabilistic estimates of the potential financial impacts of catastrophe events. The (re)insurance sector (including insurance and reinsurance companies, intermediaries and specialised catastrophe modelling firms) has developed a strong capacity for modelling the financial consequences of a wide-variety of catastrophe risks, including natural catastrophes, cyber risks, terrorism and infectious disease outbreaks. This modelling capacity has broader (if underutilised) applications to other aspects of risk management, including for informing land-use planning and building code development as well as in decisions on individual investments in risk mitigation.

The development of catastrophe models and other risk analytics tools is primarily driven by financial considerations – insurance or reinsurance companies that are significantly exposed to losses as a result of the coverage they provide for a given peril will invest in the development (or acquisition) of models to manage that exposure. As a result, the countries and perils that have the highest private sector model coverage tend to be countries and perils where there are high levels of insured exposure among private insurers or reinsurers. Perils that are highly underinsured or primarily insured by a catastrophe risk insurance programme are often not well-covered by private sector catastrophe models.

As can be seen in Figure 2.2, commercial model coverage in some countries where natural catastrophe risk insurance programmes play a significant role as coverage provider and loss absorber is more limited (e.g. Denmark (flood), Iceland (earthquake, flood, storm), France (flood), Norway (flood), Spain (flood, storm). This may suggest that limiting the role of private insurance and reinsurance markets in assuming some catastrophe risks could limit the incentives for commercial model development -– although this likely results from a variety of other factors as well such as market size and the state of model development for some perils. However, the lack of commercial modelling does not equate to a lack of overall model availability as many catastrophe risk insurance programmes have invested significantly in developing models to quantify financial impacts, often in collaboration with public sector authorities.[1]

Figure 2.2. Commercial catastrophe model coverage

	Earthquake	Flood	Storm	Wildfire
Australia				
Austria				
Belgium				
Canada				
Chile				
Colombia				
Costa Rica				
Czech Republic				
Denmark		Programme (sole)		
France	Programme (signif.)	Programme (signif.)	Programme (signif.)	
Germany				
Greece				
Hungary				
Iceland	Programme (sole)	Programme (sole)	Programme (sole)	
Ireland				
Israel				
Italy				
Japan	Programme (signif.)			
Korea				
Mexico				
Netherlands				
New Zealand	Programme (signif.)			
Norway	Programme (sole)	Programme (sole)	Programme (sole)	
Poland				
Portugal				
Slovak Republic				
Slovenia				
Spain	Programme (sole)	Programme (sole)	Programme (sole)	
Sweden				
Switzerland	Programme (sole)	Programme (sole)	Programme (sole)	
Turkey	Programme (signif.)			
United Kingdom		Programme (resid.)		
United States	Programme (signif.)	Programme (signif.)	Programme (resid.)	

Note: ▬ indicates coverage by both major modelling firms (AIR Worldwide, RMS). ▭ indicates coverage by one of the modelling firms. Countries with programmes that are the sole, significant or a residual provider of coverage for the given peril are indicated. It should be noted that the role of programmes in the US and Swiss markets varies at state or canton level.

Note: [1] In some countries where the natural catastrophe risk insurance programme have been the primary source of insurance coverage for the targeted peril, the programme has taken a large role in developing modelling and risk analytics tools. CCS (Spain) has supported the development of a modelling framework to assess geological risk with the aim of improving the quantification of potential financial impacts (Llorente Isidro, 2015[36]). The NFIP (United States) develops Flood Insurance Rate Maps to price the insurance coverage that it provides and also leverages these maps to support community resilience by providing data and risk assessments for use in long-term flood mitigation planning (NFIP, 2020[37]). In the case of terrorism, which is a risk that was not broadly modelled before September 11th, the terrorism risk insurance programmes have played an instrumental role in the development of risk analytics and modelling techniques. ARPC (Australia) has worked with a modelling firm to develop a geo-spatial catastrophe model to assess the impacts of a terrorist attack in terms of physical damage as well as business interruption as a result of the establishment of exclusion zones (ARPC, 2020[38]). CCR (France) has developed a multivariate modelling tool to assess the potential financial impacts of a Nuclear, Biological, Chemical or Radiological (NBCR) attack that assesses both the impact of an explosive device as well as the range and impact of the resulting plume through the integration of potential meteorological conditions (IFTRIP, 2017[27]). Pool Re (United Kingdom) has worked with academia to develop specific modelling capacity for non-damage business interruption resulting from terrorist attacks and a set of realistic cyber-terrorism event scenarios (Pool Re, 2020[39]), (Pool Re, 2020[40]). It also offers specific bespoke modelling solutions for terrorism risk to (re)insurance and capital markets (Pool Re, 2020[39]).

Making insurance coverage broadly available to all policyholders and for all perils – particularly where the cost of insurance is subsidised in some way – could increase moral hazard and limit the role of insurance in incentivising the implementation of appropriate risk management standards. A programme that is mandated to provide coverage to all policyholders no matter their level of risk could encourage policyholders to reside (or developers to build) in high-risk areas with little incentive to mitigate their exposure to risk (although this can be mitigated by robust land-use policies and government support for risk reduction investments). Some programmes have established eligibility criteria to address this risk. In the United States, National Flood Insurance Programme coverage is only available in communities that implement specific floodplain management measures which provides a means for the federal government to influence the risk management decisions of local governments.[55] In the United Kingdom, Flood Re's reinsurance coverage is not available for properties that have been built after 2009[56] which should encourage new developments (as well as developments since 2009) to consider the level of flood risk in decisions on location and construction standards as Flood Re reinsurance coverage will not be available to ensure the availability of primary flood insurance for developments where the level of risk is too high.[57]

Programme indemnity limits

A number of catastrophe risk insurance programmes apply indemnity limits, either as a limit on the amount of coverage that can be provided to each policyholder[58] or as a limit on the total payments that can be

[55] These requirements vary based on the flood zone where the community is located but normally include: (i) a permit requirement for all new developments within a flood zone; (ii) restrictions on new developments in flood ways (i.e. the part of a flood plain that would carry deep or high-velocity flows in the event of high water) if the development would lead to higher flood levels; (iii) new construction or replacements of damaged properties in flood zones must be elevated above base flood elevation levels (i.e. estimated water elevation for a flood with a 1-in-100 year return period); and (iv) in areas at risk of storm surge, specific building requirements must be applied to mitigate against wave strength (Kousky, 2018[32]).

[56] The decision to limit availability for properties built since 2009 was part of an agreement between insurers and the government regarding the availability of flood insurance which pre-dates the establishment of Flood Re.

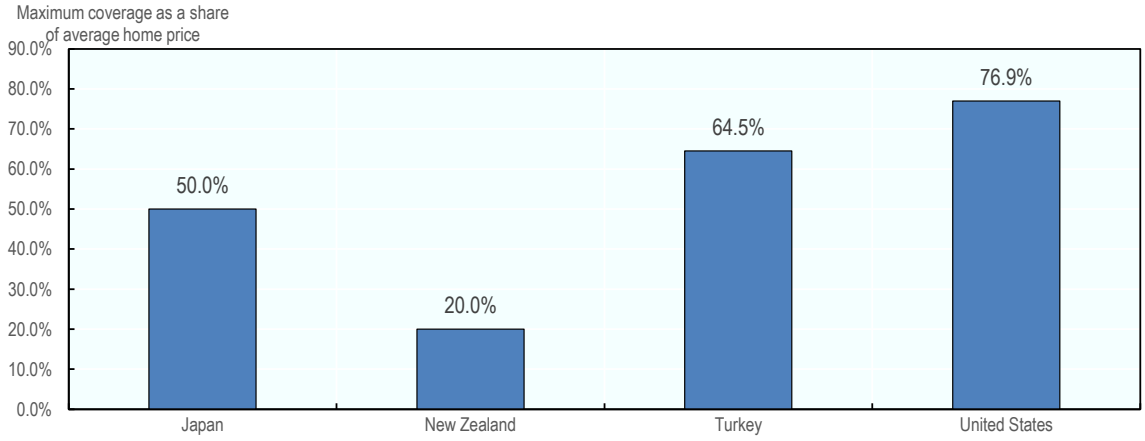
[57] Despite this limitation, some reports suggest that there continues to be significant housing development in high-risk areas in the United Kingdom (Halliday and Barratt, 2020[309]).

[58] The direct insurance coverage provided by EQC (New Zealand) is limited to NZD 150 000 (+GST). Coverage provided by NFIP (United States) is limited to USD 250 000. Coverage provided by TCIP (Turkey) is limited to 215 000 TRY. Fire insurance policyholders in Japan can acquire optional earthquake insurance coverage for 30% to 50% of

made to all policyholders in aggregate[59] (or both in some cases). Applying a limit on coverage provides a means to control programme exposure (and government exposure where programmes are backed by governments) and can also provide an opportunity for private sector insurers or reinsurers to provide supplemental (or alternative) coverage (particularly in the case of limits at the level of individual policyholders).

In some countries, individual policy limits have been set at levels that are below the full replacement value of many covered properties (see Figure 2.3). The maximum available coverage through Japan's earthquake insurance programme, EQC (New Zealand), TCIP (Turkey) and NFIP (United States) is well-below the median value of a home in each of these countries, ranging from 20% of the median value of a home in New Zealand to 76.9% in Turkey. Individual policy limits under terrorism risk insurance programmes that provide coverage for commercial properties in Austria (EUR 5 million), Belgium and the Netherlands (EUR 75 million) are also likely below the replacement costs of many commercial buildings.

Figure 2.3. Insured limits relative to median home prices



Note: For New Zealand and the United States, median home price is calculated at the national level. For Turkey, median price refers to the median price for a 100 m^2 home in six cities (Mugla, Istanbul, Izmir, Aydin, Bursa and Antalya).

the sum insured under the fire insurance policy, to a maximum of JPY 50 million in building coverage and JPY 10 million in contents coverage (JER, 2020[51]). The maximum amount of coverage available from Citizens (Florida, United States) is also limited (to USD 700 000 in 2017, down from USD 2 million in 2013 (Medders and Nicholson, 2018[35])). A number of the terrorism risk insurance programmes also apply per policy insured limits, including OVDT (Austria) (EUR 5 million), TRIP (Belgium) (EUR 75 million), NHT (Netherlands) (EUR 75 million) and Extremus (Germany) (EUR 1.5 billion) (Peters, 2020[52]).

[59] NTI (Iceland)'s liability is limited to 1% of the total sum insured per event and Norsk Naturskadpoolen to NOK 12.5 billion (World Forum of Catastrophe Programmes, n.d.[28]). The FHCF (Florida, United States) has a statutory limit on its liability of USD 17 billion per year. Flood Re (United Kingdom) has a maximum liability GBP 2.244 billion, equivalent to the limit of its reinsurance programme. In addition to the individual policy limit, the Japanese earthquake insurance programme has an indemnity ceiling of JPY 12 trillion (as of April 2021), inclusive of the government co-insurance. A number of terrorism risk insurance programmes apply annual limits equivalent to the financial capacity of the programme inclusive of government support (where applicable): OVDT (Austria)'s liability is limited to EUR 200 million per year (the programme does not benefit from government support); NHT's is EUR 1 billion; TRIP (Belgium) is EUR 1.29 billion (which increases over time); Extremus is EUR 9 billion; ARPC (Australia) is AUD 13.9 billion and TRIP (United States) is USD 100 billion (Peters, 2020[52]).

Source: OECD calculations based on (REINZ, 2020[41]), (Properstar, 2019[42]), (St. Louis Fed, 2020[43]).

While these programmes would not provide sufficient coverage to address a total loss, the amounts provided may be sufficient to absorb most losses. For example, the average claim made to the NFIP has ranged from USD 26 529 in 2010 to USD 91 573 in 2017 – well below the established indemnity limit (III, 2020[44]). In New Zealand, one estimate suggests that approximately 20% of claims resulting from the Canterbury earthquakes exceeded the NZD 100 000 limit that applied to EQC coverage at the time (Parker and Steenkamp, 2012[45]) (EQC's policy limit has subsequently been increased to NZD 150 000). Even where losses exceed policy limits, limited programme coverage may be sufficient to support the financial well-being of affected policyholders (while keeping premiums affordable).[60]

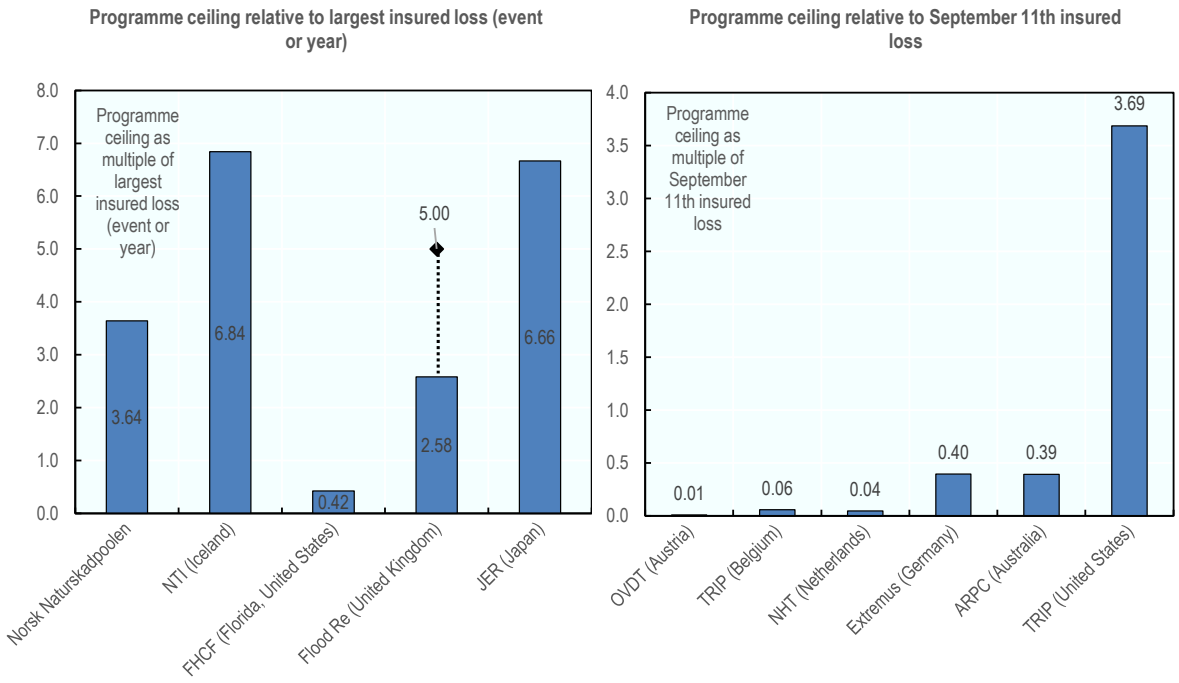
In some of the countries where programmes apply a relatively low ceiling on available coverage, private insurers offer supplemental coverage for amounts above the ceiling. For example, in New Zealand, private insurers have paid more than NZD 11 billion in claims for losses to residential (household) properties in the aftermath of the Canterbury earthquakes (ICNZ, 2020[46]) (a similar amount to the claims paid by EQC). However, in other countries, losses above the basic coverage are often uninsured.

Similarly, policyholders in countries where catastrophe risk insurance programmes apply per event or annual ceilings to the amount of coverage that they will provide could face uninsured losses if a major event or series of events within a given year exceed the programme limits. Figure 2.4 compares the indemnity limits applied to the largest natural catastrophe insured loss in each country (specific event or loss year depending on the nature of the programme limit) and to the insured losses from the September 11th terrorist attacks in the case of terrorism risk insurance programmes. Some programmes (NTI (Iceland), Norsk Naturskadpoolen (Norway), Japan's earthquake insurance programme, Flood Re (United Kingdom) and TRIP (United States)) have established programme ceilings that are well above past large events or loss years. Others, including most of the terrorism risk insurance programmes as well as FHCF, have more conservative limits that would not allow full coverage for events of similar magnitude to the most extreme events of the past (although many of these programmes only provide coverage for a portion of the insured exposure). In the case of terrorism risk insurance programmes, it should be noted that all of the programmes have ceilings that would allow full coverage for any of the events that have occurred since September 11th. Nonetheless, an extreme event or loss year resulting from a peril covered by a programme with an indemnity ceiling could lead to high levels of uninsured losses, particularly if the programme coverage is the main source of coverage for that peril.[61]

[60] In Japan, the main objective of the basic earthquake insurance policy is to stabilise the livelihoods of those affected by earthquakes, not indemnify against all the losses incurred.

[61] Many of the programmes have defined pro-rata payment approaches to allocate claims payments in the event that programme ceilings are breached. Some programmes (e.g. TRIP (United States) (Michel-Kerjan and Kunreuther, 2018[56])) also provide a legislative authority for the government or legislature to consider making payments for uninsured losses in the event that programme ceilings are surpassed.

Figure 2.4. Programme ceilings relative to large past insured losses



Note: In the case of Flood Re, the calculation was adjusted to take into account that Flood Re would only assume high-risk residential (household) policies. According to Flood Re (Flood Re, 2020[47]), approximately 30% of residential (household) properties could be considered high-risk. According to an analysis of the 2007 Yorkshire floods (largest event), approximately two thirds of damages affected residential (household) properties (Chatterton et al., 2010[48]). However, Flood Re has indicated that its assessment suggests that this ratio would be closer to 4x or 5x the largest flood loss year in the United Kingdom. In the case of JER, the calculation was adjusted to take into account that the programme only includes coverage provided by private insurers to residential (household) policyholders. According to one estimate, 78% of losses from the Great East Japan Earthquake of 2011 (largest event) were incurred by residential (household) policyholders, of which approximately 58% were incurred by residential (household) policyholders covered by private insurers (Mahul and White, 2013[49]).
Source: OECD calculations based on data on insured losses provided by Swiss Re sigma, PCS and (NTI, 2019[50]) in the case of Iceland. Information on programme ceilings is taken from (World Forum of Catastrophe Programmes, n.d.[28]), (Medders and Nicholson, 2018[35]), (Flood Re, 2020[47]), (JER, 2020[51]) and (Peters, 2020[52]).

Programme risk transfer

In most countries, catastrophe risk insurance programmes transfer some of the risk that they assume to private reinsurance (for direct insurance and co-insurance programmes) or retrocession markets (for reinsurance programmes). With few exceptions,[62] this includes both programmes that are the sole or main providers of coverage as well as those that operate as residual providers.[63] Higher levels of risk transfer by the programme to private markets reduces the programme's role in absorbing losses.

[62] Among catastrophe risk insurance programmes, only CCS (Spain) and the Danish Storm and Terrorism Insurance Councils do not transfer any programme risk to private markets (in the case of Spain, there is no legal impediment to ceding risks to reinsurers should the need arise). Also, the US Terrorism Risk Insurance Program, which operates as a provider of government co-insurance, does not cede any of the government's exposure to private markets.

[63] Direct insurance programmes in Germany, Iceland, New Zealand, Turkey and the United States (flood and California earthquake) and the co-insurance arrangements in Austria, Belgium, France, Norway and Switzerland acquire reinsurance from private markets. The reinsurance programmes in Australia, Netherlands, Switzerland, United Kingdom (terrorism and flood) and the United States (Florida hurricane) acquire retrocession from private markets. In

Many catastrophe risk insurance programmes have increased their use of private market reinsurance or retrocession over time. The NFIP (United States) has increased its traditional reinsurance protection from USD 1 million in 2016 to USD 1.153 billion for 2021 and has also accessed capital markets to provide (most recently) USD 50.28 million in proportional coverage for flooding due to named storms (Kousky, 2018[32]), (NFIP, 2021[53]). ARPC (Australia) and Pool Re (United Kingdom) have also made increasing use of private market reinsurance/retrocession capacity with retrocession coverage increasing from AUD 2.3 billion in 2005 to AUD 3.45 billion in the case of ARPC and from GBP 1.8 billion in 2015 to GBP 2.4 billion in the case of Pool Re (ARPC, 2010[54]), (HM Treasury, 2020[55]), (Peters, 2020[52]). The increased use of reinsurance/retrocession can reduce the programme's (and government's) exposure to losses (e.g. NFIP) or be used increase the amount of programme coverage available to policyholders/cedants (e.g. ARPC, Pool Re). However, the ability of a programme to transfer risk to private reinsurance or retrocession markets will be dependent on the appetite in those markets for assuming that risk. Reinsurance and retrocession market appetite may be more limited for perils that are difficult to quantify or diversify geographically (e.g. global pandemic or broad cyber-attack).

Some programmes periodically revise either programme ceilings or cost-share arrangements between the public and private sectors based on changes (sometimes anticipated) in private industry capacity to absorb losses. The Japanese earthquake risk insurance programme allocates co-insurance liability based on the level of earthquake reserves accumulated by private insurers, JER and the Government of Japan (in a dedicated Special Account for Earthquake Reinsurance). If the level of reserves accumulated by insurers and JER increases as the result of a period with few losses, their share of the programme's liability increases accordingly. The terrorism risk insurance programmes in Australia, the United Kingdom and the United States have implemented various changes to loss allocation in recent years to increase the share of losses allocated to private insurers and decrease the exposure of the programme (or government through the support provided) (see Box 2.6).

Japan, reinsurance liabilities assumed by JER are shared between JER, the government and private insurers through a retrocession arrangement.

Box 2.6. Transferring risks to private markets through increasing retentions

A number of the terrorism risk insurance programmes impose deductibles or retention requirements that apply to individual insurers and to the insurance industry in aggregate – and have increased these thresholds over time to account for increases in market capacity:

- In Australia, deductibles (retentions) are established (per event) as a share of fire insurance premiums and subject to both a company minimum and maximum deductible and an industry-wide maximum deductible. Since 2007, the company-specific deductible has been increased to 5% of the company's fire insurance premium (from 4%) and a minimum deductible of AUD 100 000 has been implemented. Maximum company and industry-wide deductibles have been increased from AUD 10 million to AUD 12.5 million and from AUD 100 million to AUD 200 million, respectively.
- In the United Kingdom, both an annual and per event industry deductible are applied and have been increased from GBP 100 million to GBP 410 million annually and from GBP 200 million to GBP 250 million per event since 2014 (HM Treasury, 2020[55]).
- In the United States, the TRIP backstop (or loss-sharing/co-insurance) is only available where industry losses exceed USD 200 million annually (an increase from USD 100 million in 2015). Individual company deductibles have increased from 1% of premiums in eligible business lines to 20% (i.e. premiums written in lines of business that are eligible for coverage under the programme) while the industry share of losses once the programme is triggered has increased from 15% to 20% (Michel-Kerjan and Kunreuther, 2018[56]). TRIP also incorporates a recoupment mechanism for co-insurance payments made by the government, involving a mandatory recoupment based on a measure of industry financial capacity (the annual average sum of all insurer deductibles over the three previous years, which is based on earned premium) as well as a discretionary recoupment for amounts not subject to the mandatory recoupment (Michel-Kerjan and Kunreuther, 2018[56]).

Premium pricing structure

A number of catastrophe risk insurance programmes do not charge premiums that fully capture variations in risk levels across different policyholders (or cedants). Many apply premium pricing structures based on sum insured (or market share in the case of co-insurance programmes).[64] Others apply broad hazard zones

[64] The catastrophe risk insurance programmes in Iceland (natural catastrophes (direct insurance)), France (natural catastrophes (reinsurance) and terrorism (co-insurance)), New Zealand (certain natural catastrophe perils (direct insurance)), Norway (natural catastrophes (co-insurance)), Switzerland (natural catastrophes in some cantons (co-insurance arranged by private insurers)), Spain (natural catastrophes and terrorism (direct insurance))) apply fixed premiums based on sum insured. The terrorism risk insurance programme in Austria (terrorism (co-insurance) also applies fixed premiums based on sum insured for some policies although other pricing approaches are also used. The terrorism co-insurance and reinsurance pools in Belgium and the Netherlands apply premiums to participating direct insurers based on market share. In Denmark, compensation for flood and NBCR terrorism losses are funded by a fee on insurance companies that is a fixed charge per written policy (applied ex post in the case of terrorism losses). In France, while the premiums charged by insurers for natural catastrophe risks are not risk-based, deductibles are higher for properties that face repetitive losses if the municipality has not implemented a risk reduction plan

or categories of construction types as the main or only criteria in setting premium rates.[65] In some cases, this is aimed explicitly at supporting solidarity across policyholders. In others, it is due to either challenges in implementing a fully risk-based pricing approach or a desire to apply a simpler pricing framework. In both cases, the outcome is likely to be some cross-subsidisation between policyholders (or cedants).[66]

Pricing for insurance (or reinsurance) coverage that varies by level of risk should – to some extent – provide an incentive for policyholders (or insurers) to invest in risk reduction in order to lower the cost of that coverage. As a result, programmes that do not price premiums based on risk may be losing an opportunity to incentivise risk reduction by policyholders. In addition, programmes that provide cross-subsidies to high-risk policyholders risk encouraging development in areas that are highly-exposed to catastrophe risks (unless effectively managed through land-use and development polices) as higher levels of risk will not be reflected in the cost of insurance coverage. Cross-subsidies may also be inefficiently targeted if they benefit wealthier policyholders that could afford to pay full premiums for a higher level of risk.

In the United Kingdom, transparency on the existence of cross-subsidies has been introduced with Flood Re through the establishment of a specific levy of GBP 180 million per annum charged to all insurers that write residential (household) property insurance coverage, allocated based on market share, to specifically subsidise the cost of reinsurance coverage for high-risk properties (with the objective of eventually eliminating cross-subsidies in flood insurance coverage). The programme also aims to improve targeting by setting premiums for Flood Re coverage based on a measure of wealth which means that wealthier policyholders in high-risk areas pay more for coverage than policyholders with more limited financial means (although some have questioned whether the measure used is effective in properly identifying low income policyholders (Surminski, 2018[57])).

Some of the programmes that do vary pricing based on risk explicitly aim to support policyholder risk mitigation, including through the use of specific discounts for risk mitigation actions taken by the policyholder (see Box 2.7). However, implementing premium discounts may be more difficult for some perils. For example, there may only be a limited set of actions that can be taken by policyholders to mitigate terrorism risk and terrorists can also adapt their methods based on measures taken which could limit the long-term effectiveness of risk mitigation action (Michel-Kerjan and Kunreuther, 2018[56]). Another challenge is ensuring that any discounts provided are actuarially sound – i.e. that the risk reduction investment actually results in lower claims levels that are consistent with the reduction in premiums that is offered. If premium discounts are larger than the corresponding reduction in losses, pricing may become inadequate. For example, legislative requirements on insurers to provide discounts for risk mitigation in Florida (United States) have reportedly led to a broad application of discounts for risk reduction measures

[65] Catastrophe risk insurance programmes in Australia (terrorism (reinsurance)), Japan (earthquake and volcanic eruption (reinsurance)), Switzerland (natural catastrophes in some cantons (direct insurance provided by public insurers for real estate)), Turkey (earthquake (direct insurance)), United Kingdom (terrorism (reinsurance)) and the United States (flood (direct insurance)) apply simplified premium structures that take into account broad risk characteristics, such as location in specified hazard zones and/or type of construction. A new premium pricing structure will be implemented by the US NFIP from October 2021 and will take into account additional factors including probabilistic assessments of inland flooding and storm surge and rebuilding cost (amongst other factors) (Hallo, 2021[71]).

[66] Programmes that focus on providing coverage to high-risk policyholders may also result in some cross-subsidisation between low and high-risk policyholders. The US residual insurance markets provide coverage to high-risk policyholders who cannot secure coverage at a reasonable rate in the private market. While these programmes normally charge premiums that are higher than average levels in the private markets, the coverage that they do provide would by definition be provided at a lower cost than available in the private market (since private market coverage is not available). Participating insurers would be exposed to losses incurred by the residual market and may therefore charge higher premiums to lower-risk policyholders to account for that exposure as a shortfall in aggregate premiums affecting a US residual market would lead to a recoupment of losses from all participating insurers (likely through charges applied to policyholders).

with limited impact and may have contributed to private insurer exits after high losses in 2004-2005 (Medders and Nicholson, 2018[35]).

Box 2.7. Premium discounts for risk reduction investments

Some direct insurance programmes provide premium discounts to policyholders (or communities) that implement risk reduction measures. The NFIP (United States) offers a variety of premium discounts for different risk mitigation measures, particularly for investments in elevating the property (supported by funding from a Federal Emergency Management Agency programme). NFIP policyholders can also benefit from premium reductions of up to 45% as a result of actions to reduce flood risk at the community-level, ranging from public information campaigns to initiatives aimed at reducing damages at the community-level[1] (Kousky, 2018[32]). The CEA (California, United States) has worked to provide progressively greater levels of discounts for certain types of mitigation investments made by policyholders – from a maximum of 5% in 2012 to up to 20% since 2016. CEA has also supported mitigation directly through a grant programme (see Box 2.3) which has ultimately led to lower premiums for many policyholders (Marshall, 2018[34]).

Some reinsurance programmes also provide premium discounts for mitigation actions. The FHCF (Florida, United States) is required to provide premium discounts and varies rates based on construction, deductible level and mitigation initiatives as well as location (Medders and Nicholson, 2018[35]). Pool Re (United Kingdom) has begun offering premium discounts of up to 7.5% for policyholders that undertake a detailed security audit of their operations (using Pool Re's Vulnerability Self-Assessment Tool or a similar standard) (Pool Re, 2020[58]). Flood Re (United Kingdom) has proposed changes to its scheme as part of its first five-year review that would allow it to offer reduced premiums rates to policyholders that have impemented resiliency measures consistent with a prescribed standard. However, it may be more difficult for reinsurance programmes to offer effective incentives for risk reduction. For example, one report suggests that the premium discounts provided by FHCF (Florida, United States) are not always passed on to policyholders and that some insurers simply divide the cost of the premium that they pay for FHCF reinsurance equally across all policyholders (Medders and Nicholson, 2018[35]).

Note: [1] Under the Community Rating System, communities are rewarded with points for risk reduction initiatives that allow the community to move through a classification system that provides 5% discounts at each higher classification level, from Class 10 (no discount) to Class 1 (45% discount) for policyholders within a Special Flood Hazard Area (Kousky, 2018[32]).

Public sector involvement

As outlined above, many catastrophe risk insurance programmes benefit from some form of government financial support. Some programmes benefit from an unlimited government guarantee for any losses that exceed the financial capacity of the programme, including any reinsurance or retrocession coverage acquired by the programme in private markets.[67] Other programmes have access to a limited government reinsurance or guarantee for losses above either a specific threshold or that are beyond the financial

[67] CCR and GAREAT (through CCR reinsurance coverage) (France), NTI (Iceland), EQC (New Zealand), CCS (Spain) and Pool Re (United Kingdom) benefit from unlimited government guarantees for losses exceeding programme financial capacity.

capacity of the programme (and its reinsurers/retrocessionnaires).[68] Japan's earthquake risk insurance programme and TRIP (United States) involve a loss-sharing arrangement between insurers and government when losses exceed a given amount (i.e. losses above the threshold are shared between the government and the private (re)insurers) - with a ceiling on overall losses. The US National Flood Insurance Program has access to loans from the US Treasury to address losses above the NFIP's capacity to pay, subject to a borrowing authority ceiling that can be adjusted through Congressional action.

Some of the programmes that benefit from government co-insurance, reinsurance, retrocession or a guarantee pay a premium or fee in exchange for the support provided. Table 2.2 provides some information on the premiums and/or fees paid by a selection of catastrophe risk insurance programmes in exchange for the government backstop.

Table 2.2. Premiums and fees paid for government reinsurance and/or guarantees

	Type of payment	Payment amount	Government coverage
ARPC (Australia)	Capital holding fee and guarantee fee	AUD 35 million and AUD 55 million	AUD 10 billion
GAREAT (France)	Premium	N/A	Unlimited
NHT (Netherlands)	Premium	N/A	EUR 50 million
Pool Re (United Kingdom)	Premium and fee (dividend)	50% of gross written premiums and 25% of any surplus[2]	Unlimited
CCR (France)	Premium	10.8% of premiums (natural catastrophe)[1] 7% of premiums (terrorism)	Unlimited
JER (Japan)	Premium (co-insurance)	Government share of collected premium based on share of overall liability	11.5662 trillion JPY
TCIP (Turkey)	Premium	N/A	EUR 240 million

Note: [1] CCR's payments to the government can be reduced to account for the cost of any retrocession arrangements made by CCR.
[2] Surplus for the purpose of this calculation is defined as earned premium and investment income net of premiums paid to commercial reinsurers and the UK Treasury, claims incurred and operating, investment and tax expenses.
Source: (Pool Re, 2020[58]), (ARPC, 2020[38]), (TRIP, 2020[59]), (CCR, 2018[60]), (Peters, 2020[52]), (Ministry of Finance, n.d.[61]).

In some countries, insurers or reinsurers do not pay any upfront premiums or fees for the government support provided through a catastrophe risk insurance programme although will be assessed post-event for some or all of the losses paid by the government.[69]

[68] ARPC (Australia), TRIP (Belgium), Extremus (Germany), NHT (Netherlands) and TCIP (Turkey) benefit from limited government guarantees for losses exceeding programme financial capacity.

[69] For example, TRIP (United States) co-insurance support is subject to a reimbursement of some or all of the payments made by the government through assessments on commercial policyholders that are collected by participating insurance companies and then remitted to the US Treasury. TRIP incorporates both a mandatory post-event assessment and a discretionary assessment to recoup any payments made by the government. The mandatory assessment applies when the total payments made by insurers in relation to the terrorism event are below the Insurance Marketplace Aggregate Retention Amount (IMARA), which is calculated annually based on the average annual sum of insurer deductibles for all insurers participating in the programme for the prior three years (equivalent to USD 40.9 billion in 2020), (Department of the Treasury, 2019[290]). Recoupment of amounts above the mandatory recoupment are at the discretion of the Treasury Secretary (FIO, 2020[69]). Payments made by Danish government for losses resulting from an NBCR terrorist attack are subject to a post-event recoupment applied to relevant lines of business. Many of the programmes that do not benefit from government co-insurance, reinsurance, retrocession or guarantees also make use of post-event assessments. Most (if not all) residual insurance markets in the United States assess insurance companies for any shortfall between premiums and claims (Hartwig and Wilkinson, 2016[291]). Citizens and FHCF in Florida (United States) and CEA in California (United States) are authorised to access debt

The different approaches to providing and charging for government financial support has implications on the amount of premiums that the programme needs to collect and therefore the affordability of the coverage that the programme provides to policyholders or cedants. For example, if the government support is triggered at a lower level of losses and is provided at a lower cost than equivalent coverage in private markets, these "cost savings" can be passed on to policyholders or cedants in the form of lower premiums:

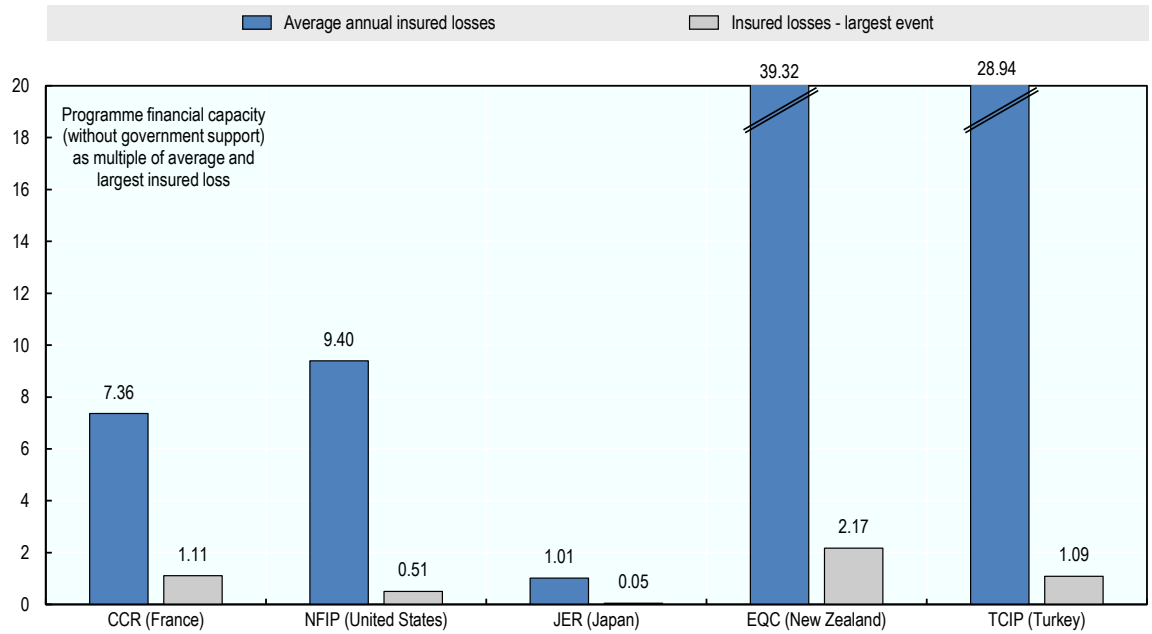
- For programmes that benefit from a limited government guarantee that is triggered at a specific loss level, it may be possible to compare the cost of the government coverage to rates for equivalent coverage in private markets (as long as such coverage is available) or to the charges applied by other countries offering similar public backstops. Programmes that are charged less for government financial backing should be able to offer some cost savings to cedants and policyholders and ultimately support affordability.[70]
- For programmes that benefit from a government guarantee (limited or unlimited) for losses exceeding the financial capacity of the programme at the time of the event, the amount of cost savings can be illustrated by comparing estimates of programme financial capacity against past losses (as a proxy for expected loss). If the programme's financial capacity is low relative to annual insured losses or insured losses from a past extreme event – the government support is more likely to be called upon in the future. If that government support is provided at no cost (or at minimal cost), the government's support to the programme is likely creating cost savings and supporting coverage affordability. As shown in Figure 2.5, most of the natural catastrophe risk insurance programmes collect sufficient premiums (and/or secure sufficient private reinsurance or retrocession coverage) to absorb losses well above average annual insured loss levels within the scope of the programme and also generally above the level of insured losses from the largest event that has occurred since 1990.[71]

markets if needed to address a funding shortfall and apply post-event assessments on insurers to repay that debt. The Florida Hurricane Catastrophe Fund and the California Earthquake Authority are also required to assess participating insurers in the event that available funds, whether held or secured through reinsurance or other risk-transfer, are depleted (Marshall, 2018[34]), (Medders and Nicholson, 2018[35]). Flood Re also has the ability to apply an assessment on insurers in the case that its losses exceed its financial capacity (Surminski, 2018[57]). The potential for post-event assessments may be considered by insurers as a potential future exposure to be reflected in current premium pricing (therefore increasing the cost of insurance) although the expectation is that insurers would normally only increase premiums in response to the assessment once applied (in some cases (e.g. California), the requirement for premium rating approval might preclude the ability of insurers to incorporate this exposure into premiums ex ante).

[70] For example, in Australia, ARPC pays fees of AUD 90 million for AUD 10 billion in retrocession coverage that is triggered once losses exceed AUD 3.9 billion (i.e. a rate of 0.009). The estimated cost of private terrorism reinsurance/retrocession acquired by terrorism risk insurance programmes is approximately 0.012 to 0.018 (OECD calculations based on reinsurance/retrocession costs reported by ARPC (Australia) (ARPC, 2020[38]), TRIP (Belgium) (TRIP, 2020[59]), Extremus (Extremus, 2020[70]) and Pool Re (Pool Re, 2020[58])). However, coverage for higher loss layers (i.e. the layers where public backing in Australia would be triggered) would normally be charged at a lower rate than lower risk layers given the reduced probability of losses at higher layers.

[71] Flood Re (United Kingdom) and CEA[71] (California, United States), which do not benefit from government support, operate at a similar level of financial resilience as the natural catastrophe programmes that benefit from government support. Flood Re's financial capacity is equivalent to approximately 2.5x to 5x (30% of) the largest insured flood loss in the United Kingdom since 1990 (2007 Yorkshire floods), assuming that Flood Re provides reinsurance coverage to approximately 30% of residential policyholders (based on an estimate of the proportion of high-risk properties (Flood Re, 2020[47])) and an estimate of the share of losses incurred by residential policyholders (66%) (Chatterton et al., 2010[48]) as well as an assessment provided by Flood Re. CEA's financial capacity is approximately equivalent to (66% of) all insured losses from the 1994 Northridge earthquake (based on an estimate of CEA's market share (CEA, n.d.[294])) although CEA only covers residential properties which accounted for approximately 50% of losses from the Northridge earthquake (as a result, CEA's capacity is likely closer to 1.2x or 1.3x the largest insured loss in California.

Figure 2.5. Natural catastrophe programme financial capacity relative to loss potential



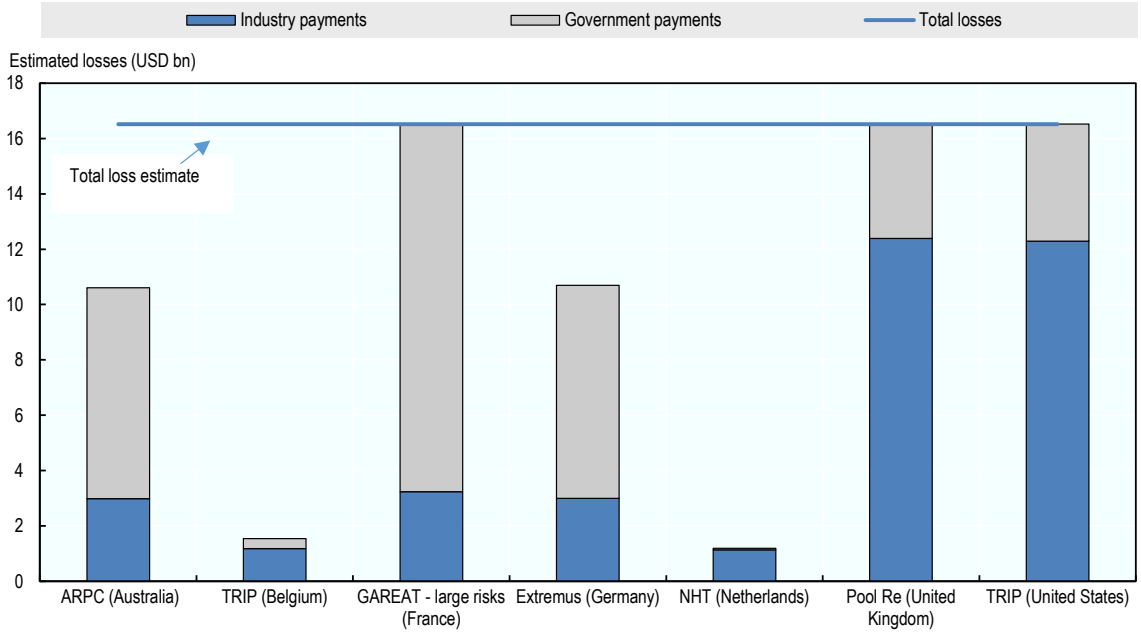
Note: For CCR (France), the insured loss estimates assume that CCR provides reinsurance coverage for 50% of losses based on CCR estimates that between 1982 and 2019 it absorbed approximately 50% of the losses from natural catastrophe events through the reinsurance coverage it provided to private insurers (CCR, 2020[62]). For NFIP (United States), the financial capacity estimates include estimated reinsurance payments calculated in (Horn, 2020[63]) but not available borrowing authority and assume 100% of flood losses are covered by the NFIP. For JER, the insured loss estimates assume that approximately 43% of insured losses fall within the scope of JER's reinsurance coverage (based on (Mahul and White, 2013[49])). For EQC (New Zealand), the insured loss estimates assume that EQC absorbs 30% of all losses based on EQC estimated gross ultimate cost from the Canterbury earthquakes of NZD 11.8 billion (EQC, 2020[64]) which equates to approximately 30% of all reported insured losses for the two major Canterbury earthquakes in 2010-2011. For TCIP (Turkey) the insured losses are assumed to be 100% covered by the programme and are overstated as TCIP only covers residential (household) property.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS (for insured losses). Programme financial capacity estimates are derived from (CCR, 2020[65]), (Federal Insurance and Mitigation Administration, 2020[66]), (TCIP, 2017[67]), (EQC, 2020[64]), (JER, 2019[68]).

Figure 2.6 provides a similar illustration for terrorism risk insurance programmes, although based on a modelled loss scenario instead of actual past losses.[72] The magnitude of the modelled loss would likely trigger the government support across all programmes although the level of government support (as well as the uninsured share of losses) would differ significantly. Under such a scenario, the government support provided in France would be the most significant (accounting for more than 80% of payouts) as a result of the relatively lower financial capacity of GAREAT and the unlimited guarantee provided through CCR. The programmes in the United Kingdom and the United States would also provide full coverage (assuming 100% take-up of coverage) although the government share would be approximately 25% in both countries. In Australia and Germany, more than half of the losses would be covered by insurance (assuming 100% take-up coverage) with governments liable for approximately 46%. In Belgium and the Netherlands, less than 10% of the losses would be covered by insurance as a result of lower programme ceilings with most

[72] The scenario is based on a terrorism event in a major urban centre (San Francisco, United States) and was defined by the US Treasury's Federal Insurance Office (FIO, 2020[69]) in the context of a 2019 data call circulated to insurance companies. The scenario provides estimates of the distribution of the resulting USD 16.52 billion in insured losses between insurers, reinsurers and the US government based on the thresholds that applied to TRIP (United States) at the time – and can be extended to make similar estimates for other programmes. The US Treasury scenario includes damages from both a conventional terrorist attack and the use of nuclear, biological, chemical, or radiological (NBCR) elements. For simplicity, it is assumed that all damages result from conventional elements.

of the insured losses covered by insurers and the programmes rather than governments (77% in Belgium and 95% in the Netherlands).

Figure 2.6. Terrorism programme financial capacity relative to a large modelled loss



Note: For ARPC and Pool Re, it is assumed that the maximum industry retention is exceeded. For TRIP and NHT, the actual industry and government payments could be smaller if the event affected only a limited number of policyholders.
Source: OECD calculations based on (FIO, 2020[69]), (Peters, 2020[52]), (ARPC, 2020[38]), (TRIP, 2020[59]), (Extremus, 2020[70]), (Pool Re, 2020[58]).

Catastrophe risk insurance programmes may also support affordability by operating at a lower level of financial resilience than would be required of private insurers or reinsurers. Due to their public policy purpose or access to government support, programmes may be permitted to collect less premiums for a given level of exposure or face more frequent underwriting losses than a private insurer or reinsurer (or its shareholders) would accept. Most of the programmes that operate as insurers or reinsurers (rather than pooling arrangements) are supervised by the national agency responsible for insurance supervision.[73] Others will often have some form of government oversight such as a Board that includes a government representative or a reporting requirement. The programmes that operate as co-insurance and reinsurance pools (TRIP (Belgium), GAREAT (France) and NHT (Netherlands) do not appear to be regulated or supervised by the insurance supervisor which may be due to their limited direct exposure to solvency risk.[74]

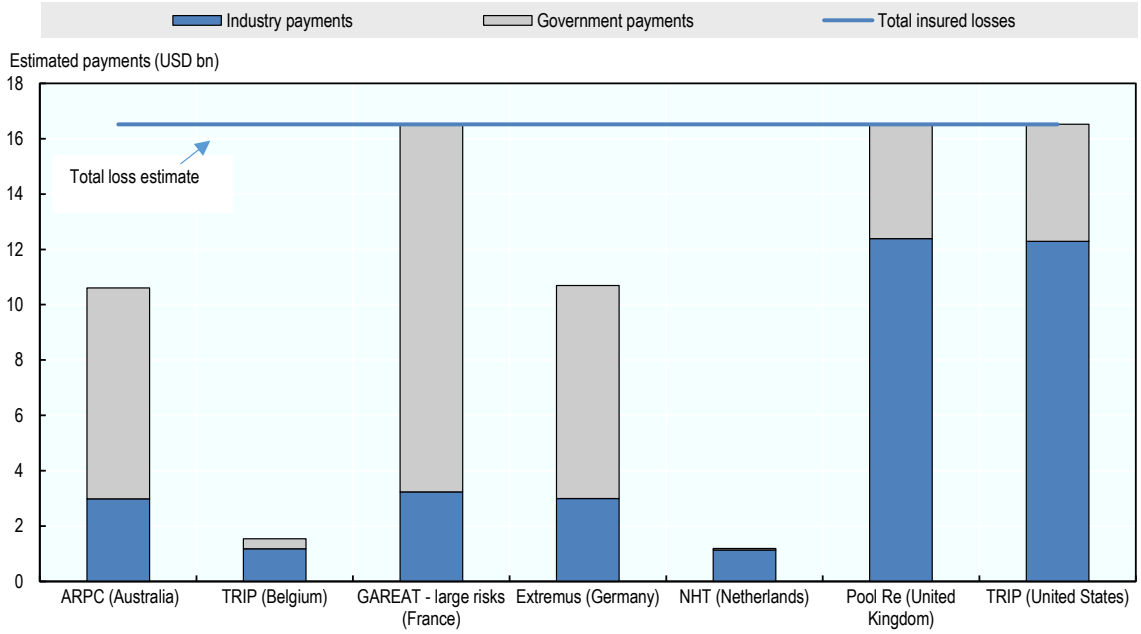
As illustrated in Figure 2.7, a number of catastrophe risk insurance programmes that offer insurance or reinsurance for natural catastrophe perils appear to operate at a level of claims to premiums (i.e. loss ratio) that would likely not be sustainable for private insurers (non-life insurers in OECD countries achieve, on average, a loss ratio of approximately 65%):

[73] Extremus (Germany), NTI (Iceland), TCIP (Turkey) and CEA (California, United States) are supervised as direct insurers and CCR (France), JER (Japan) and Pool Re (United Kingdom) as reinsurers.

[74] Most co-insurance arrangements ensure that premiums collected are fully sufficient to cover all potential liability (including through any reinsurance arrangements established by the pool).

- CCR (France) and the NFIP (United States) both appear to have operated at a loss in recent years with aggregate loss ratios significantly above 100%. While the data for both programmes is only available for a few recent years, the NFIP has likely faced regular underwriting losses over many years.[75] Planned changes to the NFIP premium pricing approach is expected to lead to higher premiums for many policyholders (Hallo, 2021[71]) and could lead to future improvements in underwriting performance.
- Flood Re (United Kingdom) has not collected sufficient premiums to cover losses over its four years of operation although, as noted above,the shortfall in premiums is deliberate and a levy applied to all insurers is meant to make up for (and has made up for) the shortfall in premium funding.[76]
- The residual insurance (Citizens) and reinsurance (FHCF) programmes in the US state of Florida have achieved loss ratios that are below 100% although substantially higher than the average loss ratio of private insurers in OECD countries.
- EQC's (New Zealand) loss ratio since 2006 has exceeded 500% in aggregate, driven by the major losses incurred as a result of the Canterbury earthquakes.

Figure 2.7. Estimated loss ratios of catastrophe risk insurance programmes



[75] Between 2004 and 2018, the NFIP faced annual average losses of approximately USD 3.5 billion (III, 2020[44]) which is more than the USD 3.4 billion collected in premiums in 2019.

[76] Including the funds collected through the levy would reduce Flood Re's aggregate loss ratio since 2017 to approximately 23%. Flood Re is reportedly designed to meet losses from a 1-in-200 year flood event, which is consistent with the supervisory requirements imposed on private insurers (Surminski, 2018[57]).

Source: OECD calculations based on (CCS, 2013[72]), (CCS, 2015[73]), (CCS, 2016[74]), (CCS, 2018[75]), (CCS, 2020[76]), (CCR, 2018[77]), (CCR, 2020[65]), (Federal Insurance and Mitigation Administration, 2018[78]), (Federal Insurance and Mitigation Administration, 2020[66]), (Flood Re, 2020[47]), (Citizens Property Insurance Corporation, 2015[79]), (Citizens Property Insurance Corporation, 2016[80]), (Citizens Property Insurance Corporation, 2017[81]), (Citizens Property Insurance Corporation, 2018[82]), (Citizens Property Insurance Corporation, 2019[83]), (Citizens Property Insurance Corporation, 2020[84]), (FHCF, 2001[85]), (FHCF, 2003[86]), (FHCF, 2005[87]), (FHCF, 2008[88]), (FHCF, 2011[89]), (FHCF, 2014[90]), (FHCF, 2017[91]), (FHCF, 2020[92]), (TCIP, 2020[93]), (TCIP, 2020[94]), (CEA, 2005[95]), (CEA, 2006[96]), (CEA, 2008[97]), (CEA, 2011[98]), (CEA, 2014[99]), (CEA, 2017[100]), (CEA, 2020[101]), (EQC, 2007[102]), (EQC, 2008[103]), (EQC, 2010[104]), (EQC, 2012[105]), (EQC, 2014[106]), (EQC, 2016[107]), (EQC, 2018[108]), (EQC, 2020[64]), (JER, 2007[109]), (JER, 2010[110]), (JER, 2013[111]), (JER, 2016[112]), (JER, 2019[68]), (JER, 2020[51]).

Programmes that provide coverage that is also available from private insurers or reinsurers and benefit from cost-savings as a result of (lower-priced) government support or lower financial resilience requirements could have an unfair advantage in the market if they are able to offer their coverage at a lower cost than private insurers or reinsurers as a result of these advantages.

While some programmes have lower levels of financial capacity relative to past losses and high claims ratios, very few have incurred losses beyond their financial capacity in the last 30 years:

- In France, losses incurred as a result of winter storms Lothar and Martin in 1999 exceeded CCR's financial capacity[77] and triggered the government guarantee for an amount of EUR 263 million (Cazaux, Meur-Férec and Peinturier, 2019[113]).
- In the United States, NFIP losses have exceeded the programme's capacity in seven of the last sixteen years, resulting in over USD 40 billion in loans from the US Treasury (Horn, 2020[63]).
- In New Zealand, the Canterbury earthquakes in 2010-2011 led to the depletion of EQC's reserves and the extension of NZD 240 million in funds from the government (as of 2020) (EQC, 2020[64]), (EQC, 2019[114]).

The Government of Japan has also incurred losses on the co-insurance that it provides. The government paid approximately 45.2% (JPY 542.2 billion) of the insured losses from the Great East Japan Earthquake in 2011 (Mahul and White, 2013[49]).

[77] Under the natural catastrophes regime in France, the state guarantee may be triggered if the losses exceed 90% of CCR's provisions and special reserves (Cazaux, Meur-Férec and Peinturier, 2019[113]).

3 The contribution of programmes to addressing low levels of insurance coverage

As outlined in the previous section, the catastrophe risk insurance programmes that have been established to address low levels of insurance coverage of natural catastrophe and terrorism risks incorporate a variety of different approaches in terms of the type of insurance coverage offered, the scope of the programme's operations, the premium structure applied and the involvement of the public sector. The following sections examine the available evidence on the contribution of existing programmes to achieving broad coverage of catastrophe perils and limiting public sector exposure.[78] This is followed by a discussion of the potential role that such programmes could play in supporting higher levels of insurance coverage in other countries and for other perils.

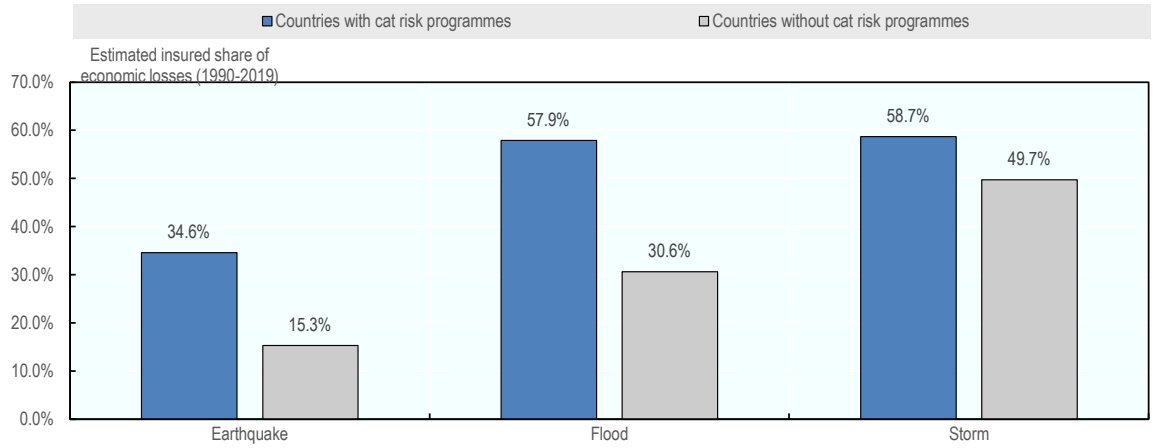
The contribution of existing programmes to increasing insurance coverage

Supporting broad insurance coverage for catastrophe perils

The effectiveness of efforts to improve the availability and affordability of insurance for catastrophe perils can be evaluated in terms of whether those efforts lead to broad coverage for the targeted peril(s). For the main natural catastrophe perils (earthquake, flood, storm), the share of economic losses covered by insurance between 1990 and 2019 was higher (on average) in countries with a catastrophe risk insurance programme although with a smaller difference in the case of storm losses (see Figure 3.1).

[78] The contribution of catastrophe risk insurance programmes to reducing the overall level of risk is much more challenging to measure given the variety of factors that impact the level of catastrophe losses (such as changes in the frequency or intensity of natural hazards, population growth, etc.). The impact of the indirect contribution of catastrophe risk insurance programmes through the application of risk-based insurance premiums (where applicable) is difficult to measure as there are few studies that have specifically measured the impact on differential pricing on policyholder's willingness to invest in risk reduction. The direct financial support for risk reduction funded by catastrophe risk insurance programmes – while important – is unlikely to account for a significant share of total investment in risk reduction in most countries or regions.

Figure 3.1. Insured share of economic losses in countries with and without catastrophe risk insurance programmes (1990-2019)



Note: Countries with catastrophe risk insurance programmes include: for earthquake (France, Japan, New Zealand, Spain, Turkey (2000-2019) and the US state of California (2000-2019); for flood (Denmark, France, Norway, Spain, Switzerland, United States) and for storm (France, Norway, Spain, Switzerland, United States). The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 1990-2019 for countries with and without programmes; and (ii) the average insured share of losses across countries with and without programmes, calculated based on the average share of insured losses for each individual event. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS.

However, these averages hide some significant differences between countries and programmes:

- In the case of earthquakes, the multiple peril programmes in France and Spain as well as the limited peril programme in New Zealand have achieved levels of insurance coverage that are much higher than other countries that have faced earthquake losses while Japan, Turkey and California (United States)[79] have continued to face high levels of uninsured earthquake losses.
- In the case of floods, the multiple peril programmes in France, Spain and Switzerland and the compensation arrangement in Denmark have achieved high levels of insurance coverage that are significantly higher than other flood-prone countries. The share of flood losses insured is also very high in the United Kingdom, although this was also true before the establishment of Flood Re. The share of flood losses insured in the United States is lower than many other countries.[80]

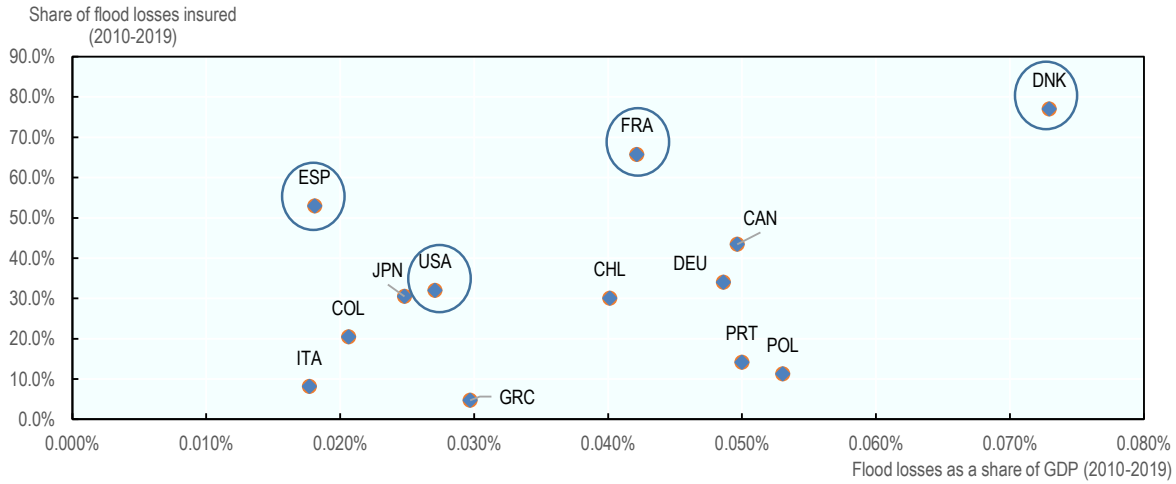
A number of countries that are highly-exposed to catastrophe perils have achieved higher levels of insurance coverage through catastrophe risk insurance programmes than countries with similar levels of

[79] At the time of the Northridge earthquake in 1994, more residential policyholders had purchased earthquake coverage, particularly in the San Fernando Valley in the Los Angeles area (the epicentre of the Northridge earthquake). The mandatory offer requirement had been in effect since 1985 and coverage was relatively inexpensive in general (up to and including the year of the Northridge earthquake) leading to higher take-up. Immediately after the Northridge earthquake, the earthquake insurance (and residential property insurance market more generally) was severely disrupted until the year immediately following the inception of CEA.

[80] One of the frequent criticisms of the NFIP is that the designation of high-risk zones discourages those outside the zones from acquiring coverage even though they remain at risk of flooding (Kousky, 2018[32]). One study of the NFIP cited estimates of 60% take-up in Special Flood Hazard Areas in the South and West and 20% to 30% in the Midwest and noted that other studies had found that only 20% of those impacted by Hurricane Sandy (2012) and only 12% of those impacted by severe floods in Baton Rouge (Louisiana) in 2016 had flood insurance (Kousky, 2018[32]).

relative exposure but without a programme. For example, New Zealand faced losses from earthquakes between 2010 and 2019 that were 5.5 times higher than Italy, 10 times higher than Mexico and more than 35 times higher than Greece as a share of GDP yet achieved insurance coverage levels that were 4 times to 10 times higher. Figure 3.2 provides an illustration for the case of floods between a number of countries that faced similar levels of relative losses. The countries that achieved the highest level of insurance coverage were those with programmes covering flood risks (Spain, France and Denmark).

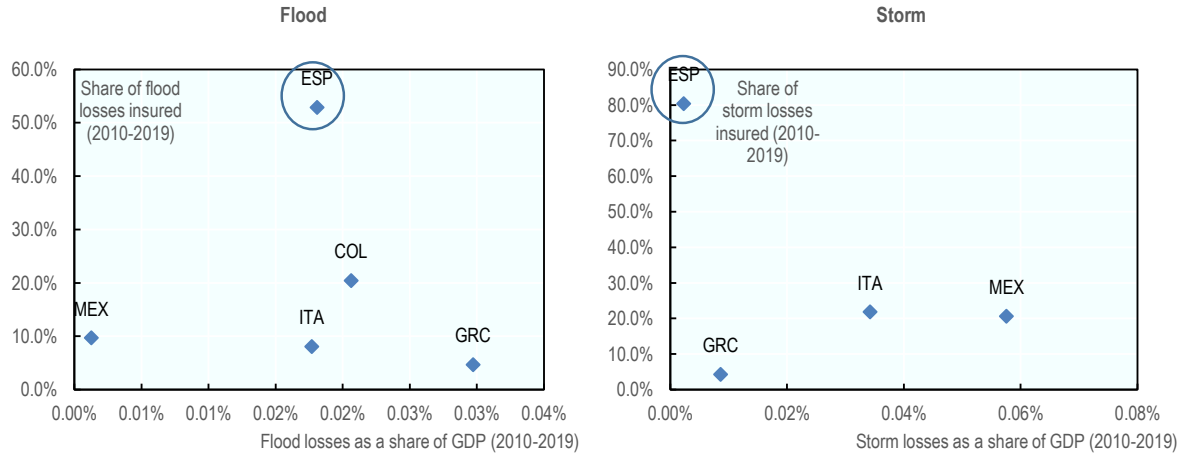
Figure 3.2. Flood insurance coverage in countries with similar levels of exposure



Note: The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 2010-2019; and (ii) the average insured share of losses across countries, calculated based on the average share of insured losses for each individual event.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS.

Catastrophe risk insurance programmes also likely contributed to a higher share of insured losses in countries with lower levels of overall property insurance penetration. For example, Spain has a comparable (but lower) property insurance penetration rate (property premiums as a share of GDP) to Mexico, Greece, Colombia, Turkey and Italy – although a much higher level of insurance coverage for floods and storms (see Figure 3.3).

Figure 3.3. Flood and storm insurance coverage in countries with similar property insurance penetration rates



Note: The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 2010-2019; and (ii) the average insured share of losses across countries, calculated based on the average share of insured losses for each individual event.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS and (OECD, 2020[115]).

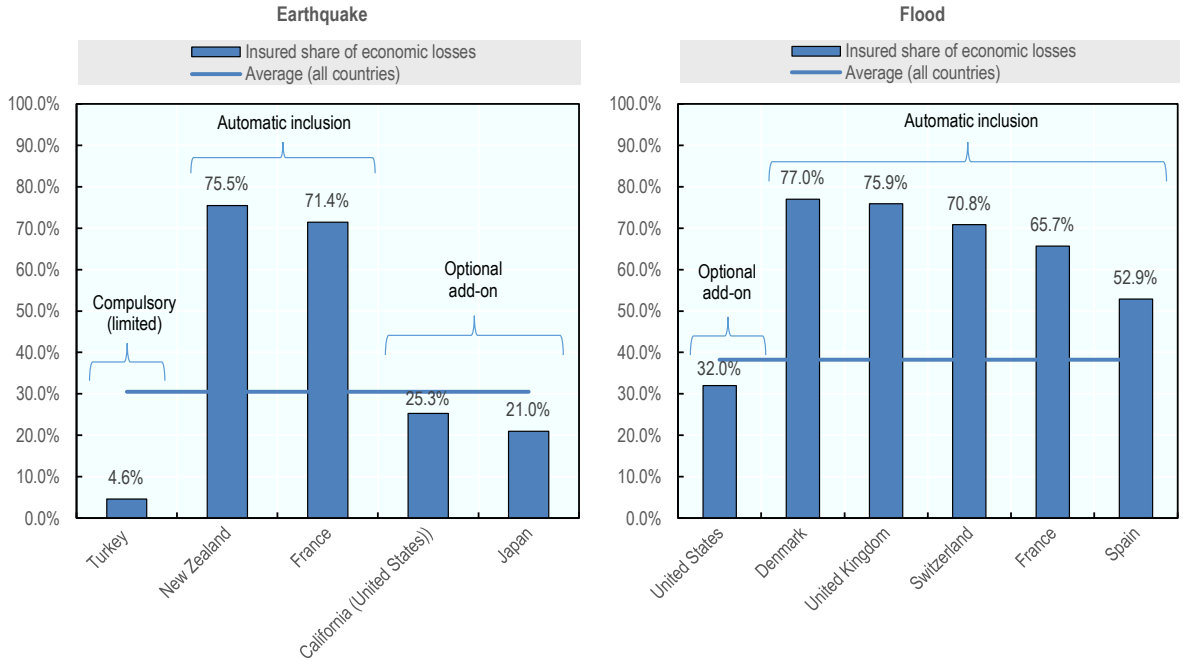
One of the key drivers of the effectiveness of a catastrophe risk insurance programme in supporting high levels of insurance coverage appears to be how the coverage is offered to policyholders. As shown in Figure 3.4, countries where the coverage provided by catastrophe risk insurance programmes is integrated into property policies (i.e. automatic extension of property coverage to include the targeted peril(s))[81] achieved a much higher level of coverage than countries where the catastrophe programme coverage is provided as an optional add-on[82] – or even where some form of compulsory acquisition applies to only a sub-set of policyholders.[83]

[81] In the case of flood risk, the programme coverage in Denmark, France, Norway, Spain and the United Kingdom is incorporated into property insurance policies and levels of coverage for flood losses are much higher than in countries without a catastrophe risk insurance programme applicable to this peril. In the case of earthquake risk, the programme coverage in France, New Zealand and Spain is automatically included in property insurance coverage and the share of earthquake losses insured was much higher than in other OECD countries without a catastrophe risk insurance programme for earthquake losses.

[82] In California (United States) and Japan, earthquake insurance must be offered to residential policyholders although policyholders can opt out which has led to a lower level of coverage of earthquake losses (although still near or above the OECD average).

[83] In the United States, flood coverage offered by the National Flood Insurance Program (or private insurers) is provided as a separate coverage and only compulsory for properties located in a designated flood zone and with a loan from a federally-regulated lender. In Turkey, earthquake insurance is mandatory for policyholders although only within municipal boundaries and subject to some historical challenges in terms of enforcement of this requirement.

Figure 3.4. Insured share of earthquake and flood losses by coverage approach (2010-2019)



Note: The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 2010-2019; and (ii) the average insured share of losses across countries, calculated based on the average share of insured losses for each individual event. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS.

The relatively low number of terrorist attacks precludes a similar examination of the potential impact of terrorism risk insurance programmes on achieving broad levels of coverage. Similar to natural catastrophe risk insurance programmes, some (in fact most) terrorism programmes integrate coverage into property insurance policies for commercial policyholders[84] although some include this coverage as an optional add-on or endorsement.[85]

[84] In France and Spain, property policies are automatically extended to include terrorism risk. The attack on Madrid Barajas airport caused major property damage in 2006 and was mostly insured (the attack on the railway network in 2004 led to personal injury payouts by CCS due to deaths and injuries although not insured property damage). There have been no attacks in France that have resulted in major property damage. In Australia, terrorism coverage is automatically included in commercial property insurance policies as a result of a legislative provision that voids terrorism exclusions in the event of a declared terrorist incident. Insurance coverage for terrorism is compulsory for some lines of business in Belgium (including simple fire risk) and the share of losses insured in the context of the 2016 attacks on a metro station and airport in Brussels was also relatively high (more than 50%).

[85] In the United Kingdom, all of the major terrorist attacks that have occurred since the establishment of Pool Re (and that have caused major property damage) have been well-insured – with the exception of the 2005 attack in London that targeted public transport. In the United States, insurers are required to offer terrorism insurance to commercial policyholders on the same basis as coverage for other perils which has led to generally stable levels of take-up in the range of 60% to 80% (Michel-Kerjan and Kunreuther, 2018[56]).

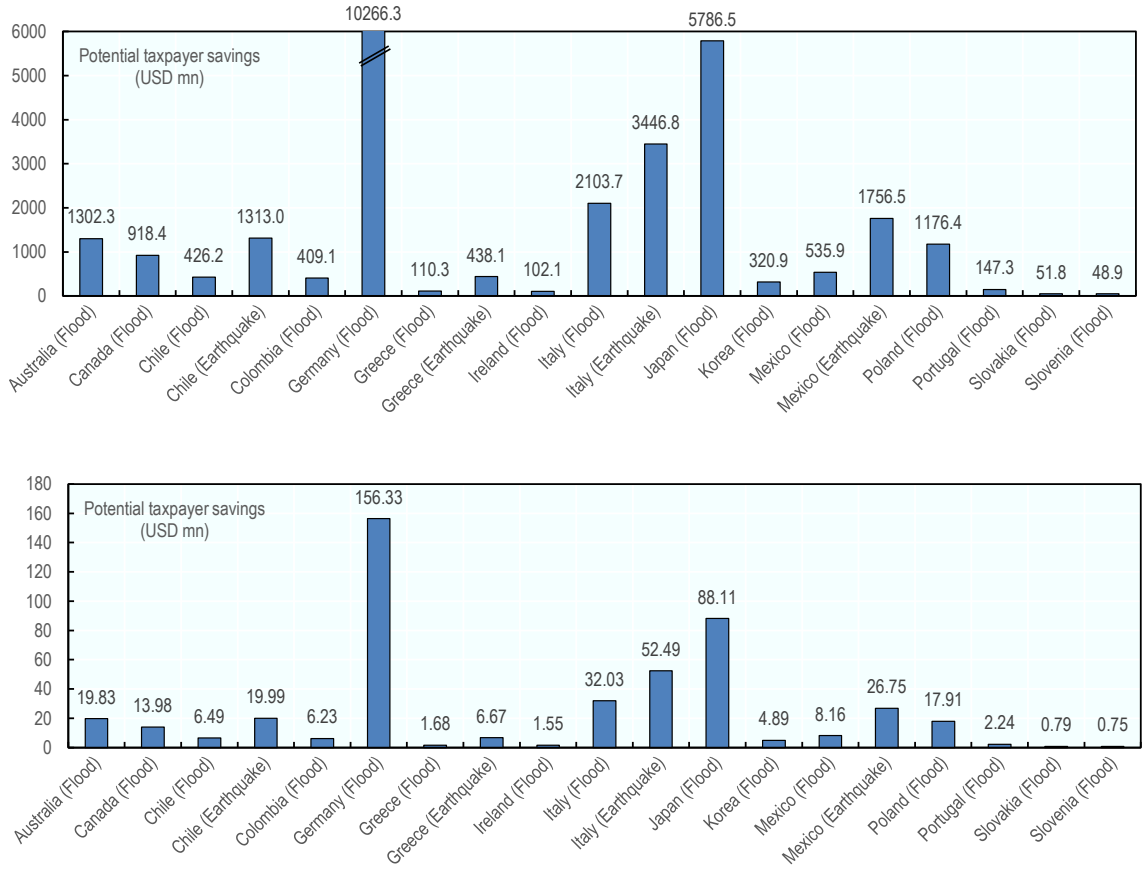
Limiting public sector exposure

As noted above, over the last 30 years, most catastrophe risk insurance programmes have operated without a need for significant investment of government funds to absorb losses (although, depending on fiscal rules and programme structures, some governments may set aside funds *ex ante* as capital to back potential exposures to programme losses). Only a few programmes have faced losses beyond their financial capacity:

- EQC (New Zealand) has required (thus far) NZD 240 million in funding from the New Zealand Treasury to address losses related to the Canterbury earthquakes (equivalent to approximately 2% of the insurance payments made by EQC or 0.6% of overall economic losses).
- CCR (France) has required EUR 263 million in funding from the French Treasury to address losses related to winter storms Martin and Lothar in 1999 (equivalent to approximately 7% of CCR's share of insured losses (assuming CCR paid 50% of insured losses) or 2.4% of overall economic losses from the two events).
- NFIP (United States) has faced relatively frequent underwriting losses that have required loans from the United States Treasury, approximately every alternate year for a total of over USD 40 billion (equivalent to approximately 23.2% of the insured losses or 5.8% of overall economic losses from flooding during that period). NFIP also receives government appropriations for its mapping functions.

More significantly, where the establishment of a catastrophe risk insurance programme has led to broader insurance coverage of losses, the pressure on governments to compensate households or businesses for uninsured losses has likely been reduced. Many countries have programmes to provide grants or loans to households and businesses after a disaster event to support recovery and, in some cases, reconstruction. One set of OECD/World Bank case studies estimated that post-disaster spending has accounted for the vast majority of government expenditure on disaster risk management in most of the countries studied and that ex post government expenditures were equivalent to approximately 4% of the estimated amount of annual losses in Colombia, 9% in Australia, 12% in Mexico and 38% in Japan (OECD/The World Bank, 2019[116]). Another study of specific past large events estimated that an increase in insurance penetration of 1% is linked to a reduction in post-disaster government expenditure equivalent to 22% of the damages incurred (Lloyd's, 2012[13]). Figure 3.5 provides an illustration of the potential cost savings to taxpayers that could materialise (generated from these estimates). The graph on the top applies the cost-savings estimate from the Lloyd's study of a 1% increase in coverage to the difference between insurance coverage levels in countries with and without catastrophe risk insurance programmes (from Figure 3.1). The graph on the bottom applies the estimate of post-disaster expenditure from the OECD/World Bank study (as a share of uninsured losses, using the case of Australia) to the difference in coverage levels. While these estimates are far from perfect, they can provide a general sense of the potential savings to public finances from an increase in insurance coverage supported by the establishment of a catastrophe risk insurance programme.

Figure 3.5. Illustrative potential costs annual savings to taxpayers from the implementation of a catastrophe risk insurance programme



Note: The graph on the top assumes that a 1% increase in the share of losses insured leads to a reduction in post-disaster government expenditure equivalent to 22% of damages. The graph on the bottom assumes that governments absorb approximately one third of uninsured losses, estimated based on the annual amount of post-disaster government expenditure in Australia as a share of uninsured losses incurred. The estimates assume that a catastrophe risk insurance programme could increase the level of coverage to either (the lower of) the share of losses covered by insurance in countries with catastrophe risk insurance programme for the specific peril or an estimate of the increase in the share of losses covered by insurance based on the difference in coverage levels between countries with and without programmes (i.e. a 226% increase in the case of earthquakes and a 189% increase in the case of floods).
Source: OECD calculations based on data provided by Swiss re sigma and PCS, (OECD/The World Bank, 2019[116]), (Lloyd's, 2012[13]).

Any decision to invest in the establishment of a catastrophe risk insurance programme should also take into account the potential benefits relative to the alternative of investing directly in risk reduction or other measures that support the insurability of catastrophe perils by private insurance and reinsurance markets. Public policy can support the insurability of catastrophe perils in a number of ways. Investments in risk communication and education and limitations on the availability of post-disaster financial assistance could enhance the willingness of households and businesses to acquire insurance coverage. Improvements to land-use planning and investments in security, risk mitigation and resilience could reduce the level of likely damages and losses and therefore the cost of insurance coverage.

Increasing financial protection through a catastrophe risk insurance programme

As described in Annexes A-D, a number of countries face continued low-levels of financial protection for natural catastrophe perils, cyber risks and infectious disease outbreaks where no catastrophe risk insurance programme has been established.

Natural catastrophe perils

A few countries face significant exposure to multiple catastrophe perils, low levels of insurance coverage and relatively low levels of property insurance penetration. Greece and Italy have faced large losses from earthquakes, floods and storms (as well as wildfires in the case of Greece) with very low levels of insurance coverage (less than 8% in Greece across all perils and less than 13% in Italy in the case of floods and earthquakes). Portugal has also faced large losses from floods, storms and wildfires and is highly exposed to earthquake risk despite few earthquake losses in recent decades. Levels of insurance coverage for floods and particularly storms are higher in Portugal. Mexico has faced significant losses from earthquakes and storms and relatively low levels of insurance coverage for those losses (although higher than in Greece for all perils and in Italy in the case of earthquakes). All four countries have relatively low levels of property insurance penetration. As a result (and if desired), these four countries might be able to increase levels of insurance coverage through the establishment of a catastrophe risk insurance programme that provides some direct insurance coverage for multiple perils.

A number of countries face high-levels of exposure to flood risk and relatively lower levels of insurance coverage. Poland and Slovak Republic are mainly exposed to flood risk and have faced high-levels of uninsured losses (approximately 85% to 90% of flood losses were uninsured in Poland and 95% in Slovak Republic). These two countries also have relatively lower levels of insurance penetration. Slovenia faced high-levels of losses from floods between 2010 and 2019 and very low levels of insurance coverage despite a higher level of property insurance penetration overall. Canada and Germany have also faced high flood losses in recent years (and increasing losses in the case of Canada) and relatively low levels of insurance coverage (approximately 36%-50% in Canada and 27%-40% in Germany between 2010 and 2019) despite high levels of property insurance penetration (Canada is also exposed to earthquake risk although no losses have been incurred since at least 1990). A catastrophe risk insurance programme targeting flood risks could potentially contribute to higher levels of insurance coverage in some of these countries. In the countries with low property insurance penetration, a direct insurance programme might be most effective. In Canada, consideration could be given to some form of reinsurance or residual programme.

Japan has faced large flood and storm losses in recent years which are not within the scope of its catastrophe risk insurance programme. Storm losses have been increasing (and could continue to increase) although levels of insurance coverage remain relatively high (69% of storm losses between 2010 and 2019 were covered by insurance). The level of insurance coverage for flood losses is much lower (approximately 25% to 35%).

In some other countries, insurance coverage levels remain high although there are some signs of insurability challenges for some climate-sensitive perils (e.g. wildfire in California (United States), cyclones in Northern Australia). The need to establish a catastrophe risk insurance programme could emerge if insurers begin (or continue to) withdraw coverage as a result of increasing losses. Given the high levels of current insurance coverage and high property insurance penetration rates, a reinsurance or residual programme might provide the best option for these specific challenges. On 4 May 2021, the Government of Australia announced plans to establish a government-backed reinsurance programme for cyclone wind and flood damage for residential (household) and small business policyholders in Northern Australia (Australia Treasury Ministers, 2021[117]).

In all cases, it may be prudent to begin by requiring insurers to make coverage available, increasing risk awareness among households and businesses and reducing expectations of post-disaster government assistance. Insurability challenges that need to be addressed by the establishment of a programme are

more likely to come to light if insurers are required to offer coverage and policyholders are demanding coverage.

As outlined in the previous section, the decisions on the design of a catastrophe risk insurance programme involve a number of trade-offs in terms of the different approaches to achieving broad coverage while limiting public sector exposure and supporting risk reduction:

- Efforts to support affordability through cross-subsidisation between policyholders can blunt incentives for risk reduction and can raise issues of fairness if cross-subsidies benefit those that could afford to pay higher premiums. Allowing programmes to benefit from low or no cost government financial support or to operate at lower levels of financial resilience can support affordability although may put taxpayers at risk and raise competition concerns if the coverage provided by catastrophe risk insurance programmes is also available from private insurers or reinsurers.
- Limiting the scope or amount of coverage provided by a catastrophe risk insurance programme to specific perils or policyholders can reduce public sector exposure although may lead to gaps in coverage and can also reduce the ability of the programme to benefit from diversification.
- Catastrophe risk insurance programmes can play an important role in developing modelling and risk analytics tools – particularly for perils that have not traditionally created significant exposure for private insurers or reinsurers – although limiting private sector involvement in the assumption of risk could hamper the development of private sector models and analytics.
- Catastrophe risk insurance programmes can provide a source of expertise and funding to support risk reduction although their capacity to contribute will depend on the scope of the coverage that they provide (and the amount of premiums that they collect).

Cyber risk

The level of underinsurance for cyber risks appears to be high across all countries, driven largely by challenges that would be common to any relatively new line of insurance coverage (lack of awareness, policyholder unfamiliarity with coverage details, fewer or less developed risk analytics tools). Thus far, the losses have not been unmanageable and have mostly been incurred by businesses which are more likely to have the financial resources to absorb such losses.

Most idiosyncratic cyber attacks such as targeted ransomware attacks and data breaches are likely to continue to be insurable[86] in private markets even if frequency and severity continues to increase. However, some of the drivers of cyber insurance may be more enduring (and increasing in severity), particularly the potential for increasing digitalisation and concentration in information technology services to lead to large-scale simultaneous losses affecting many policyholders around the world. This possibility is likely an important factor in the limited availability of excess-of-loss reinsurance coverage[87] and the common application of infrastructure exclusions in reinsurance (and therefore insurance) coverage for cyber risk.

As a result, the most effective government intervention (if desired) might be some form of government backstop, potentially provided to reinsurers (rather than insurers), for very high-severity losses in order to support the availability of excess-of-loss reinsurance coverage from private reinsurance markets. A recoupment requirement could be applied in order to reduce (or eliminate) the exposure of taxpayers to losses. Consideration could be given to limiting the types of events that could qualify for this type of

[86] As outlined below, ransom payments may not be insurable due to legal or policy restrictions in some countries or circumstances.

[87] Reinsurance and capital markets are responding to constraints in the availability of excess-of-loss reinsurance coverage for cyber risks through the development of new products and increasing capital investment.

government backstop to those linked to a nation-state actor as the motivation of nation-states is more likely to be political (rather than criminal) and nation-state linked actors might be the only attackers with the capacity to implement a truly catastrophic cyber attack.

Infectious disease outbreaks

Addressing underinsurance of business interruption losses related to infectious disease outbreaks is likely to be more challenging than in the case of natural catastrophe or cyber perils:

- Risk measurement, particularly for business interruption losses, is likely more challenging given the variety of uncertainties that could arise (frequency of outbreaks, transmissibility and severity, capacity of public health systems to manage impacts, duration of the outbreak including time for vaccine development, decisions by public authorities on mitigation measures such as confinement measures).
- The losses resulting from infectious disease outbreaks that become global pandemics cannot be diversified by insurers or reinsurers and may be correlated with financial markets which would limit the availability of both reinsurance and insurance-linked securities market capacity.
- Depending on frequency and duration, the magnitude of losses could be multiples of the losses that could potentially materialise as a result of other types of catastrophe events.

These challenges would likely require a larger government role in providing coverage for pandemic-related business interruption losses than for other types of catastrophe perils. However, it is not a certainty that every future infectious disease outbreak will become a global pandemic or that every future pandemic will require the types of confinement measures that resulted in large business interruption losses in the context of COVID-19.

The approach taken to providing terrorism reinsurance coverage in Australia may offer a relevant solution. The reinsurance coverage is only triggered when an event is designated as a terrorist incident which could have parallels to the declaration of a public health emergency requiring confinement measures. More importantly, the declaration of a terrorist incident voids any applicable terrorism exclusions in commercial property insurance policies which ensures that coverage is applicable when a declaration is made. This approach would allow insurers to apply exclusions (or provide affirmative coverage) for less severe infectious disease outbreaks while making government reinsurance available for the high-severity outbreaks that are beyond the capacity of insurance companies to absorb.

Annex A. Natural catastrophe perils

Natural catastrophe perils, including weather-related perils such as flood, storms and wildfires as well as geological perils such as earthquakes (see Box A.1), are a significant source of insured and economic losses in many countries around the world. Between 1990 and 2019, earthquakes, floods, storms and wildfires caused an estimated USD 2.9 trillion in economic losses in OECD member countries – USD 96.5 billion on average each year.[88]

[88] OECD calculations based on data provided by Swiss Re sigma. Includes all reported economic losses.

Box A A.1. Natural catastrophe perils and data sources

This report focuses on a sub-set of natural catastrophe perils - storms, floods, wildfires and earthquakes:

- Catastrophe storm perils include: (i) convective storms (commonly referred to as thunderstorms) which may lead to strong winds (including tornadoes) and heavy precipitation (including hail, ice and snow); and (ii) cyclones (often referred to as hurricanes in the Western hemisphere, typhoons in Asia and windstorms in Europe) which usually create very strong winds and heavy precipitation. In coastal areas, heavy winds can also lead to storm surge. Storms can lead to wind damage and water damage although water damage (including storm surge) is normally classified as flood damage.
- Catastrophe flood perils include: (i) riverine (fluvial) flooding which may result from heavy precipitation or snow melt that causes bodies of water to overflow onto adjacent (normally dry) land; (ii) coastal flooding which may result from tidal variations or storm surge; and (iii) flash (pluvial) flooding which results from heavy precipitation at levels that are above the absorption capacity of the ground.
- Forest fires are a natural phenomenon that occur regularly in forests around the world, normally in remote unpopulated areas with limited impacts on buildings or people. Catastrophic wildfires can occur when forest fires that are difficult to control occur in populated areas that are located close to forests or grasslands, in areas commonly referred to as wildland-urban interface zones.
- Catastrophic earthquakes can result in damages and losses as a result of the direct impact of ground-shaking on buildings (which can also lead to fires) as well as by causing landslides, tsunamis and/or liquefaction (i.e. where sediments at the surface lose strength as a result of the ground-shaking).

There are a number of other weather and geological catastrophe perils, such as volcanic eruptions, droughts, hail, avalanches and heatwaves and cold/frost events that were excluded from the analysis, either because the number of events was low or because most losses from these types of perils are covered under other lines of insurance business, such as crop insurance or motor vehicle insurance. That said, some of these perils create significant risks for some countries and are often underinsured. For example, a severe volcanic eruption of Mount Vesuvius near Naples (Italy) could lead to approximately USD 40 billion in property damage (Munich Re, 2020[118]), most of which is likely to be uninsured as insurers in Italy do not normally offer coverage for damage from volcanic eruption (Gizzi, Potenza and Zotta, 2016[119]) (policyholders in other large cities at risk in New Zealand and Japan can access coverage through a catastrophe risk insurance programme).

There are low levels of insurance coverage for natural catastrophe perils in many OECD countries. Between 1990 and 2019, approximately 58% of economic losses from earthquakes, floods, storms and wildfires were uninsured.[89] Levels of insurance coverage vary significantly for different perils:

- Storm-related losses accounted for the majority of catastrophe-related economic losses across OECD countries between 1990-2019 (58.7%) of which close to 45% were uninsured;
- Earthquake losses accounted for 25.7% of reported economic losses over the period, of which approximately 82% were uninsured;

[89] OECD calculations based on data provided by Swiss Re sigma and PCS. Includes reported economic losses only for events for which an insured loss estimate is also available.

- Flood-related losses accounted for 12.3% of reported economic losses, of which 71% were uninsured.
- Wildfire losses accounted for the smallest share of economic losses among the four perils (3.1%) and the highest level of insurance coverage (63%).

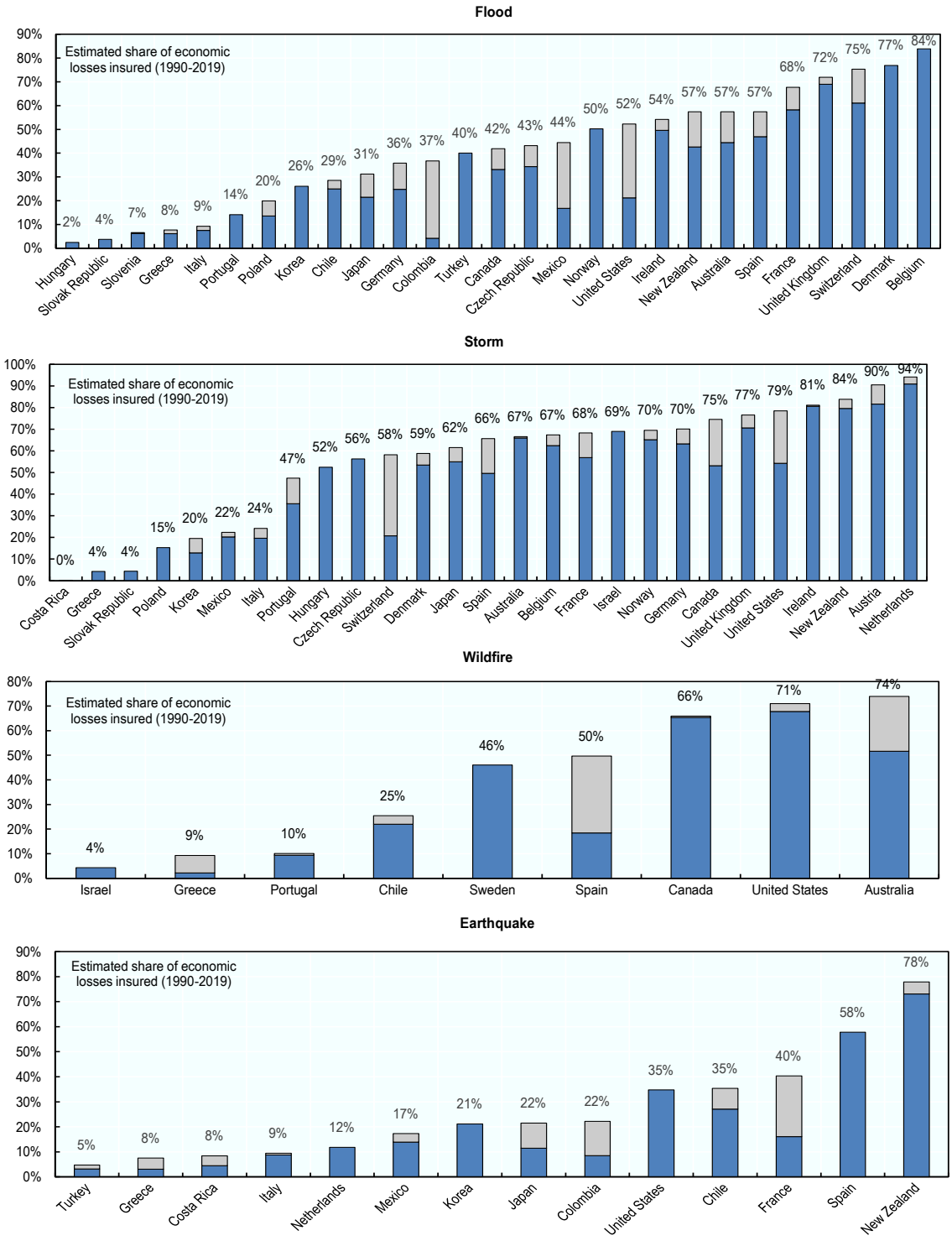
The share of economic losses insured varies significantly across OECD countries. Based on two estimates of the share of economic losses insured since 1990[90]:

- The share of storm losses insured since 1990 is estimated to be above 50% in most OECD countries with the exception of Costa Rica (close to 0%), Greece (4%), Slovak Republic (4%), Poland (15%), Korea (20%), Mexico (22%), Italy (24%) and Portugal (47%) (using the higher estimate).
- The share of earthquake losses insured is less than 30% in most earthquake-prone countries, with the exception of the United States (35%), Chile (35%), France[91] (40%), Spain (58%) and New Zealand (78%) (using the higher estimate).
- The share of flood losses insured is below 50% in most countries, with the exception of Norway (50%), United States (52%), Ireland (54%), New Zealand (57%), Australia (57%), Spain (57%), France (68%), United Kingdom (72%), Switzerland (75%), Denmark (77%) and Belgium (84%) (using the higher estimate).
- The share of wildfire losses insured varies substantially across countries – from less than 20% in Israel (4%), Greece (9%), Portugal (10%) to more than 50% in Canada (66%), the United States (71%) and Australia (74%) (using the higher estimate).

[90] The first estimate is the share of aggregate losses since 1990 that were insured (only for events where both economic and insured losses were reported). The second estimate is the average of the share of insured losses for each individual event which aims to eliminate any data bias created by large events (high economic losses) with low reported insured losses (or vice versa).

[91] There were only two reported earthquake events in France over the period, with very different levels of insured losses (9% of economic losses in the case of the 1996 earthquake in Epagny and 71% in the case of the 2019 earthquake in Le Teil).

Figure A A.1. Share of economic losses insured by peril (1990-2019)



Note: The chart shows two estimates: (i) the aggregate share of all economic losses insured (1990-2019); and (ii) the average of the insured share of losses for each individual event. The data label refers to the higher of the two estimates. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.

Source: OECD calculations based on data provided by Swiss Re sigma and PCS. Includes reported economic losses only for events for which an insured loss estimate is also available.

Potential drivers of natural catastrophe underinsurance

Form of coverage

The differences in the share of losses covered by insurance for different perils across countries are likely driven (at least in part) by differences in how insurance coverage is offered (as well as by differences in the overall level of property insurance penetration – see Box A.2):

- Across most OECD countries, **storm (wind) damage** is a standard coverage included in property damage (and business interruption) policies for residential (household) and commercial (business) policyholders. In some countries exposed to cyclonic winds, coverage may only be available as an endorsement or through a catastrophe risk insurance programme or may be subject to different coverage terms. For example, in France and Spain, damage from winds above a certain velocity are included in separate (automatically included) coverage for natural catastrophes (France)/extraordinary risks (Spain) which are ultimately backed by a government guarantee. In Norway, storm is included among the perils covered in a catastrophe risk pooling arrangement established by insurance companies. In Switzerland, storm is covered by public insurers for real estate in cantons that have established such entities. In many US states, specific hurricane or windstorm deductibles (higher than other deductibles) are applied to wind damage due to a named storm.[92] Many US states have also established residual insurance arrangements (often referred to as beach and wind plans) to provide coverage for households and businesses that are unable to secure coverage from private insurers at a reasonable cost. Water damage, whether resulting from precipitation or storm surge is usually treated as flooding from an insurance perspective.
- Insurance coverage for **wildfire damage** is included in standard property insurance coverage in almost all (if not all) countries and is normally treated as any other damage from fire. There are currently no catastrophe risk insurance programmes that provide coverage for wildfire damage although the public insurers for real estate in Switzerland include fire as a peril in their coverage as do the residual plans established in many US states.
- Insurance coverage for **flood damage** is more varied than in the case of storm and is covered by catastrophe risk insurance programmes in a number of countries. In some countries, coverage for all forms of flood are included in standard property insurance coverage (e.g. United Kingdom). In others, coverage for some types of flooding are included while other types are excluded. For example, in Australia, coverage for pluvial and fluvial flooding is included in most residential (household) property insurance policies although flooding caused by storm surge is sometimes excluded (Finder, 2020[120]). In other countries, coverage for all or some types of flooding is only offered as an optional endorsement, either alone or as part of optional coverage for catastrophe perils (e.g. Germany, Italy). In a few countries, insurance coverage for flood (or some types of flood) is not available at all (e.g. Netherlands) or has only become available in recent years (e.g. Canada). The multi-peril catastrophe risk insurance programmes in France, Iceland and Spain provide coverage for flood as do the public insurers for real estate established in most Swiss cantons and the catastrophe pooling arrangement in Norway. In Denmark, a programme to provide compensation for inland flood and storm surge damage has been established and is funded by a fee on fire insurance premiums. In the United States, insurance coverage is provided by a public insurance programme, the National Flood Insurance Program, as well as (more recently) by private

[92] The definition of when a hurricane deductible (rather than the normal policy deductible) applies varies across policies but is often linked to whether the event is a named storm and/or whether a hurricane watch has been declared. At the time of writing, hurricane or windstorm deductibles are applied in 19 US states, usually calculated as a share of the insured value of the property (III, 2020[268]). The application of hurricane deductibles is overseen by state insurance commissioners and is subject to specific legislative or regulatory requirements in some states.

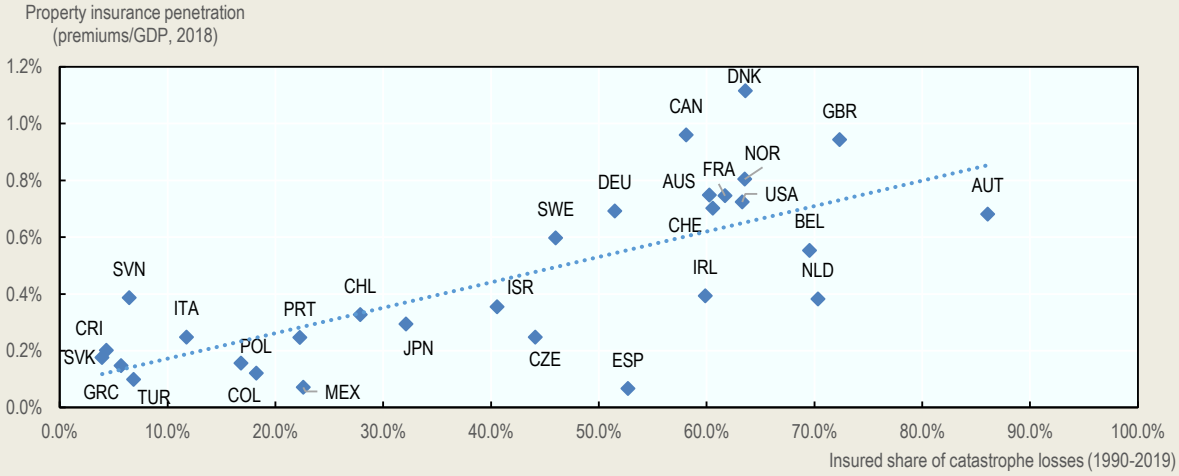
insurers. In the United Kingdom, a flood reinsurance programme has been established (Flood Re) to assume risk from private insurers in high-risk areas. In New Zealand, flood damage to land (but not buildings) is covered by the public Earthquake Commission.

- Insurance coverage for **earthquake risk** is often only provided as an optional endorsement to property insurance policies (for earthquake alone or for numerous catastrophe perils). A number of highly-exposed jurisdictions have established catastrophe risk insurance programmes focused on providing coverage for earthquakes (and, in some cases, limited other perils), including Japan, New Zealand, Turkey and the US state of California. Earthquake coverage is also included in the coverage provided by the multi-peril catastrophe risk insurance programmes (or pools) in France, Iceland, Norway and Spain. Insurance coverage for earthquake often also covers damages and losses resulting from fire following earthquake, tsunami and (to a lesser extent) liquefaction (although in some countries, including the United States, tsunami losses are included in flood insurance coverage).

Box A A.2. Property insurance penetration and low levels natural catastrophe insurance coverage

The overall penetration of property insurance in a given country is a potential factor in the level of uninsured catastrophe losses as countries where a large share of households or businesses are without property insurance are likely to face more uninsured losses – no matter which perils are normally included in the property insurance that is acquired. A number of countries with relatively low levels of property insurance penetration, such as Greece, Turkey, Colombia and Mexico, have faced relatively lower levels of insurance coverage for catastrophe losses since 1990. However, the standard measure of insurance penetration (premiums to GDP) can be misleading as premium levels depend on both the number of households and businesses that acquire insurance as well as the cost which would be expected to be higher in countries facing higher levels of risk.

Figure A A.2. Property insurance penetration and share of catastrophe losses insured

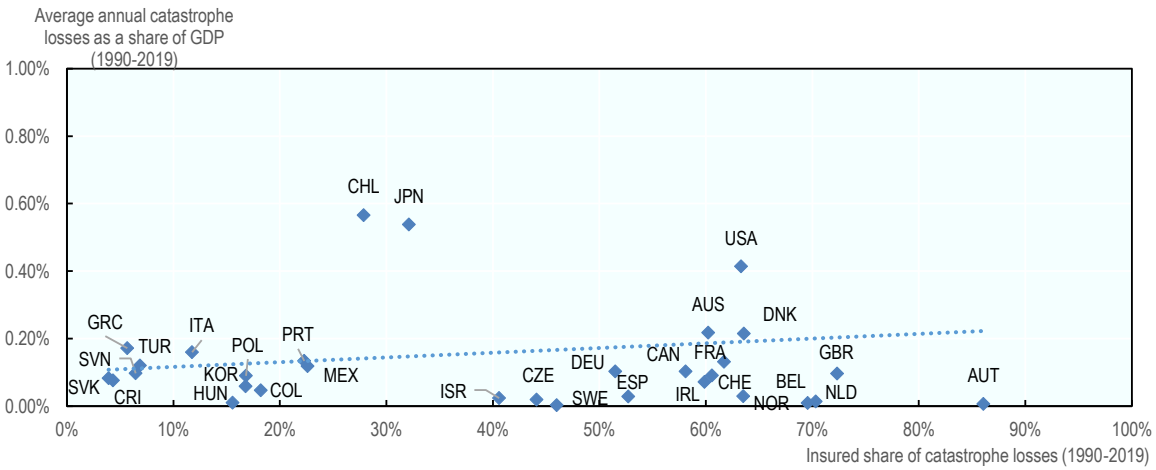


Note: Data was not available for Hungary, Korea and New Zealand. The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 1990-2019; and (ii) the average insured share of losses across countries, calculated based on the average share of insured losses for each individual event. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on data provided Swiss Re sigma and PCS and (OECD, 2020[115]). Includes reported economic losses only for events for which an insured loss estimate is also available.

Loss magnitude

Differences in the level of insurance coverage for natural catastrophe perils across countries might also be related to differences in the relative level of exposure to natural catastrophe risk. Insurers in countries that face higher losses from natural catastrophes would need to charge higher premiums for insuring those risks which may lead to lower levels of insurance coverage if policyholders are unwilling or unable to pay higher premiums. Figure A.3 shows the relationship between average annual economic losses from storms, wildfires, earthquakes and floods as a share of GDP and the share of those losses that have been insured. There does not appear to be a relationship between the level of catastrophe exposure in a given country and the share of losses suggesting that differences in catastrophe exposure are not a significant driver of differences in levels of insurance coverage.

Figure A A.3. Magnitude of catastrophe losses and share of catastrophe losses insured



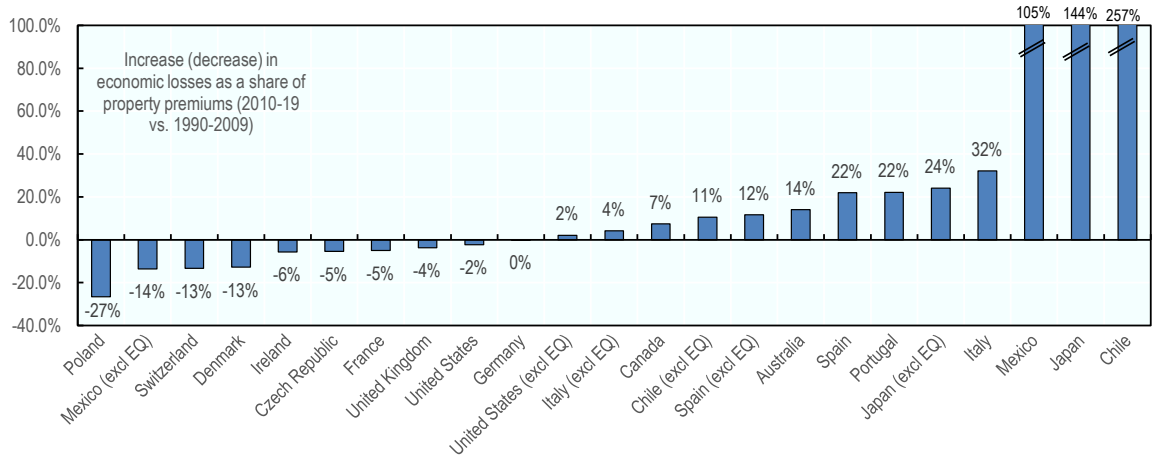
Note: New Zealand (not shown) had a significantly higher level of average annual losses to GDP (1.2%) and a high share of insured losses (77%). The estimate of insured share of economic losses is the mid-point of (i) the insured share of aggregate economic losses between 1990-2019; and (ii) the average insured share of losses across countries, calculated based on the average share of insured losses for each individual event. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible. Source: OECD calculations based on data provided Swiss Re sigma and PCS and (OECD, 2020[121])

Increasing natural catastrophe losses could also be a potential driver of low insurance coverage levels as the expectation of high losses could lead insurers to increase the cost of insurance to levels above the willingness-to-pay of more policyholders. Economic losses in OECD countries from storms, floods, wildfires and earthquakes have increased over time from an average annual loss across countries of USD 58.6 billion between 1990 and 2009 to USD 89.5 billion between 2010 and 2019, an increase of almost 53%.[93] Annual average economic losses in 2010-2019 were 217% higher in the case of wildfires, 141% in the case of earthquakes, 56% higher in the case of storms and 39% higher in the case of floods relative to 1990-2009 although with significant variation across countries.

A number of countries faced large increases in natural catastrophe economic losses although others did not. Figure A.4 illustrates the increase (or decrease) in economic losses as a share of property premiums in 2010-2019 (relative to 1990-2009) for a set of countries for which sufficient data on premiums and catastrophe losses were available. For countries that have faced large earthquake losses in one period but not the other (Italy, Mexico, Japan, Spain, United States and Chile), the figure provides estimates with and without including earthquake losses (given the impact of large earthquakes on identifying trends in the data). Economic losses from natural catastrophes were higher in Japan (including and excluding earthquake from the data), Portugal, Spain, Australia, Chile and Canada and were marginally higher in Italy and the United States (excluding earthquake). The increase in Canada resulted from an increase in wildfire and flood losses. Portugal was faced with higher storm and flood losses between 2010 and 2019 while Spain faced higher losses from floods. In Australia and Japan, floods and storms drove higher losses in 2010-2019 (along with earthquakes in the case of Japan). A number of other European countries saw a reduction in economic losses as a share of premium between 2010 and 2019 relative to previous years.

[93] OECD calculations based on data provided by Swiss Re sigma. Includes all reported economic losses.

Figure A A.4. Increase (decrease) in natural catastrophe economic losses (2010-2019 vs. 1990-2009)



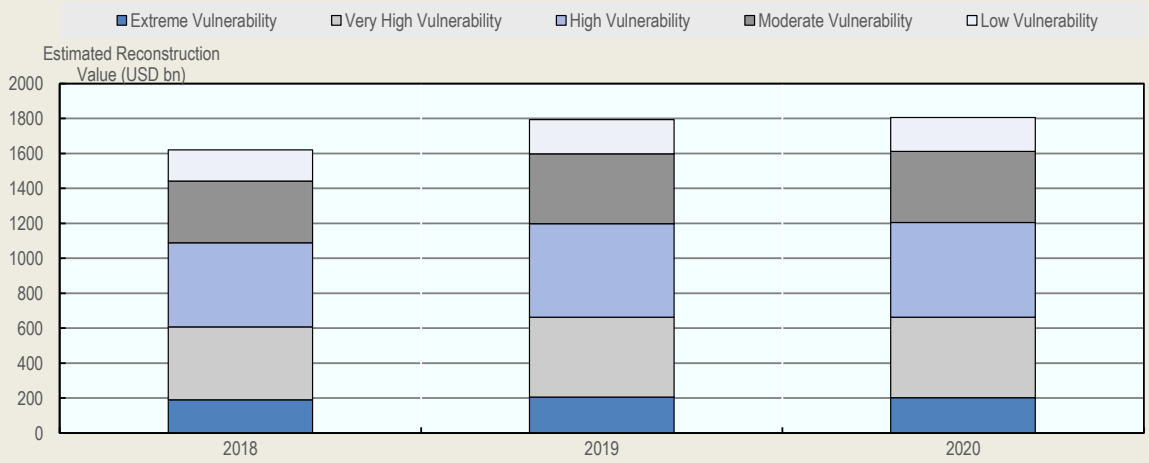
Source: OECD calculations based on data provided by Swiss Re sigma and (OECD, 2020[115]).

Some of the increase relates to increases in the value of assets exposed (see Box A.3, for example) and the cost of rebuilding although growth in economic losses from these natural catastrophes has outpaced the growth in GDP across OECD countries (the aggregate average annual GDP of OECD countries was 32.5% higher between 2010-2019 relative to 1990-2009). There were also likely improvements in data collection for more recent years which could explain part of the increase in reported economic losses.

Box A A.3. Increasing assets at risk

Despite improving knowledge and understanding of potential hazards, at-risk regions in many countries continue to attract inflows of people and development and face increases in the value of assets exposed to damage from natural hazards. In the United States, the value of coastal exposures in the Atlantic and Gulf of Mexico regions has grown at an annual rate of approximately 4% for a number of decades, driven by both population growth and higher construction costs (AIR Worldwide, 2020[122]). Figure A.5 illustrates the growth in the total estimated reconstruction value of houses exposed to storm surge risks in the Atlantic and Gulf of Mexico regions of the United States since 2018. According to these estimates, USD 184 billion in exposure (reconstruction value) has been added since 2018 with growth across all categories of vulnerability (particularly among high and moderate vulnerability).

Figure A A.5. Estimates of total reconstruction value of storm-surge exposed homes: United States



Note: Extreme vulnerability refers to homes that could be damaged by storms of various levels of intensity (category 1-5 hurricanes) whereas low vulnerability refers to homes that are only likely to be damaged by a severe (category 5) storm. Reconstruction values are estimated based on a 100% loss assumption.
Source: OECD calculations based on (CoreLogic, 2018[123]), (CoreLogic, 2019[124]), (CoreLogic, 2020[125])

A significant driver of wildfire risk is the development of the wildland-urban interface (WUI). In the United States, WUI zones are home to more than 120 million people, several hundred thousand businesses and approximately one-third of all residential buildings (Wisch and Yin, 2019[126]). In the 15 US states[1] most prone to wildfires, the total reconstruction value for homes at moderate to extreme risk of wildfire (accounting for 6.5% of all single family homes in these states) was estimated to be USD 644 billion in 2020 (CoreLogic, 2020[127]). In California, more than 10 000 additional homes have reportedly been built in high-risk wildfire zones in the last decade (Cape Analytics, 2020[128]). A mapping of the WUI in European countries in 2016 identified a number of regions where WUI zones accounted for a significant share (>10%) of the land area, including in Western Germany, Eastern France, Belgium and Switzerland and around a number of large Scandinavian cities (Oslo, Goteborg, Stockholm and Helsinki). Across Mediterranean regions, WUI zones accounted for a lower share of land cover although were still approximately 4% of land cover in parts of France and Portugal (Modugno et al., 2016[129]).

[1] Alaska, Arizona, California, Colorado, Florida, Idaho, Montana, New Mexico, Nevada, Oklahoma, Oregon, Texas, Utah, Washington and Wyoming.

Higher economic losses may also be driven by an increase in the frequency or intensity of hazardous events. For weather-related natural catastrophes, a changing climate is expected to have (or may already be having) a significant impact on the magnitude of losses (see Box A.4).

Box A A.4. The potential impact of a changing climate on catastrophe frequency and severity

The characteristics of future storm (wind) hazard could be impacted by climate change although there is significant uncertainty and differing assessments about some of the implications for storm activity from rising sea and air temperatures (and other related future climate characteristics):

- The frequency of cyclone formation overall (on a global-basis) could decrease in a warmer climate with some regional variation (e.g. frequency could increase in the northeast Pacific (US state of Hawaii, Pacific coast of Mexico)) (Knutson et al., 2015[130]). An analysis of historical data on tropical cyclones found that the likelihood of a major tropical cyclone (i.e. winds reaching 100 knots, equivalent to a Category 3 hurricane) occurring increased by 49% per decade between 1979 and 2017 in the North Atlantic basin and 18% per decade in the Southern Indian Ocean with a potential link to increasing ocean temperatures (Kossin et al., 2020[131]).
- A higher share of the cyclones that do form may be more intense with a predicted increase in overall cyclone intensity and more frequent high-intensity (category 4 and 5) cyclones – particularly in the Northern hemisphere basins. More intense storms would lead to stronger winds (estimated increase of 1% to 10%) and more precipitation (estimated increase of 10% to 15%) (Knutson et al., 2015[130]), (GFDL, 2020[132]). A number of recent Atlantic basin cyclones (Hurricanes Laura, Sally and Michael as well as Harvey, Irma and Maria in 2017) intensified rapidly prior to landfall (Slocum, 2020[133]) which some studies have linked to climate change factors such as marine heatwaves (Dzwonkowski et al., 2020[134]). More frequent rapid intensification prior to landfall has also been observed in recent cyclones that have impacted China (Yao et al., 2020[135]).
- There is evidence, in all basins except the Atlantic, of a poleward shift in the latitude where tropical cyclones achieve their maximum intensity (referred to as lifetime maximum intensity or LMI) which has been linked to the emergence of more favourable conditions for cyclone intensification away from the equator (and less favourable conditions nearer to the equator) (Kossin, Emanuel and Vecchi, 2014[136]).
- The frequency and intensity of severe convective storms (i.e. storms that generate high winds, large hail and/or tornadoes) is related to whether favourable conditions for storm development (convective available potential energy and strong wind shear) are present. Increasing atmospheric humidity is expected to increase convective available potential energy although disproportionate warming in the Arctic is expected to reduce wind shear strength in the areas most prone to severe convective storm development (Brooks, 2013[137]). In some regions, the increase in convective available potential energy with greater atmospheric humidity is expected to override the decrease in wind shear strength. One study estimates that, under a high emissions scenario, favourable conditions for severe convective storm formation could become 50%-180% and 40%-120% more common in the United States during the spring and summer, respectively, by the end of the 21st century (Seeley and Romps, 2015[138]). A similar analysis applied to Europe suggests an increase of more than 20% in lightning frequency (6-hour periods subject to lightning) in Northern and Eastern Europe (and a smaller increase in Central Europe) in the last quarter of the 21st century under a high-emissions scenario (Rädler et al., 2019[139]).

A changing climate is expected to have a number of potential implications for the level of flood risk across countries:

- Changes in precipitation patterns will affect flood risk. There is a high level of uncertainty regarding whether average annual precipitation will increase or decrease in different regions although a general conclusion that currently dry (low precipitation) areas are likely to become

drier and currently wet regions will become wetter. It is also likely that more precipitation will fall as rain rather than snow as a result of rising temperatures (Hausfather, 2018[140]) which could lead to higher levels of flood risk overall (i.e. the increase in rainfall-driven flooding is likely to offset the reduction in snow melt-driven flooding (Davenport et al., 2020[141]), (The Geneva Association, 2020[142])). Most climate models predict that there will be higher levels of precipitation during winters in North America and winters, springs and autumns in Northern Europe and drier summers. Mediterranean regions are expected to face drier springs, autumns and (potentially) winters. Predicted changes in Oceania, Asia and South America are less pronounced although with some decreases in precipitation predicted for parts of Australia and Brazil during summer and autumn and Chile across all seasons (Hausfather, 2018[140]). One recent analysis predicts that, based on changing precipitation patterns and continued socioeconomic development, the number of people affected by riverine floods globally will more than double from 65 million in 2010 to 132 million in 2030 while the number of people affected by coastal flooding will increase from 7 million to 15 million over the same period (Kuzma and Luo, 2020[143]).

- There is also some consensus that extreme rainfall events will occur more frequently in almost all regions of the world (i.e. even where annual precipitation levels are not expected to change significantly) – with the exception of Australia and some countries in Central America and North and Southern Africa (Fischer et al., 2014[144]). In North America, for example, a 1°C increase in global mean surface air temperature relative to pre-industrial climate (i.e. 1°C of warming), could lead to a reduction in the return periods for extreme precipitation events for 1-in-20 to 1-in-5, 1-in-50 to 1-in-10, and 1-in-100 to 1-in-20 – with a decline in return periods expected for most parts of the continent at 1°C in warming and for all but the South Central region at 2°C of warming (Kirchmeier-Young and Zhang, 2020[145]). Extreme precipitation creates particular challenges as flooding can occur when the amount of precipitation exceeds the capacity of the ground to absorb that precipitation (exacerbated in built-up areas where absorption capacity is much more limited).
- The frequency of extreme precipitation is also related to changes in storm frequency and intensity. More frequent or more intense cyclonic or convective storms will impact the frequency of extreme precipitation events (in fact, storms have been identified as a likely driver of the expected increase in the share of overall precipitation that comes in the context of extreme rainfall events (Witze, 2018[146])). Some climate models have projected higher precipitation levels attached to more intense cyclones as a result of global warming (Liu et al., 2019[147]). Other studies have shown a relationship between changing wind patterns and a reduction in the forward speed of cyclones (i.e. often referred to as translation speed - how quickly they pass over an area) (Kossin, Emanuel and Vecchi, 2014[136]), (Zhang et al., 2020[148]) although there remains some debate about these findings (Moon, Kim and Chan, 2019[149]), (Yamaguchi et al., 2020[150]). Hurricane Harvey (2017) and Hurricane Florence (2018) both had limited forward movement and set records as the “wettest” tropical cyclones to ever impact Texas and the Carolinas (respectively) (AIR Worldwide, 2020[151]). Typhoon Hagibis in Japan in 2019 also released unprecedented amounts of rainfall which resulted (at least partially) from slower forward movement (Sousounis, 2019[152]) (along with a lifetime maximum intensity that occurred further north than most previous cyclones) (Freeman, 2019[153]).
- Coastal flooding risk is likely to increase as a result of rising sea levels which can lead to increased tidal flooding as well as greater inundation as a result of storm surge. One recent study estimated that, without any investments in coastal adaptation, approximately 52% of the global population and 46% of global assets will be at risk of flooding by 2100 under the high emissions RCP 8.5 scenario, driven by tidal events, storm surge and sea-level rise. The study identified a number of “hotspots” that are expected to face larger areas of flood inundation,

including Northwest Europe (especially France and the United Kingdom), Northeast United States, Northern Australia, Western Korea as well as parts of China, India and Southeast Asia (Kirezci et al., 2020[154]). In Korea, one estimate suggests that, using the high emissions RCP 8.5 scenario, land inhabited by more than 3.3 million people could be submerged as a result of sea-level rise (Dong-hwan, 2020[155]). In the United States, rising sea levels could lead to a doubling of coastal flood risk as current 1-in-50 year extreme water levels could be exceeded annually in 70% of coastal regions by 2050 (Taherkhani et al., 2020[156]). The combination of sea-level rise and changes in tropical cyclone activity could reduce the return period of current 1-in-100 year coastal flooding to annual occurrence in New England and the mid-Atlantic and to every 1 to 30 years in the Southeast Atlantic and Gulf of Mexico regions by 2100 under a high-emissions scenario (Marsooli et al., 2019[157]). In Europe, one study suggested that, under the high emissions scenario, annual damages resulting from coastal flooding could increase to EUR 239 billion by 2100 with the largest losses affecting Germany, Denmark, France, Italy, the Netherlands and the United Kingdom (Ciscar et al., 2020[158]). Another study estimates that wind-generated extreme wave heights (i.e. maximum observed wave heights with a return period of 1-in-100 years during the period 1979-2005) could increase by 5% to 15% in the Southern hemisphere oceans, by 5%-10% in the high latitudes of the North Pacific and approximately 10% in the high latitudes of the North Atlantic (with a decrease in extreme wave height in the low latitude regions of the North Atlantic) (Meucci et al., 2020[159]).

Rising temperatures and more frequent heatwaves and droughts as a result of a changing climate could increase the likelihood of wildfire occurrence. According to one estimate, fire weather seasons (i.e. periods of time where weather conditions are conducive to the outbreak of wildfires) have lengthened across 25% of the earth's vegetated surface (Jolly et al., 2015[160]). By 2030-2040, a changing climate could extend fire seasons by three months in Western Australia, more than two months in parts of Northern California and one month in Greece, Spain and Portugal (Four Twenty Seven, 2020[161]). An analysis of potential future European wildfire risk identified the potential for significant increases in the number of days with high or extreme wildfire risk in Spain, Portugal and Turkey and some areas of Greece, central and southern Italy and France (particularly for a 3°C warming scenario) and smaller increases in at-risk days in the southern United Kingdom, Belgium and parts of the Netherlands and Germany (Costa et al., 2020[162]).

In addition to the direct damages and business interruption losses that are incurred as a result of natural catastrophe, there is a large potential for indirect losses as a result of disruptions to critical infrastructure services due to damages to service delivery infrastructure such as transmission lines (see Box A.5).

Box A A.5. Critical infrastructure failure

A prolonged disruption to critical infrastructure services, such as power, telecommunications or water, also has the potential to lead to significant losses as a result of the impact of the disruption on economic activities. Many commercial property insurance policies provide some coverage (either automatically or through endorsement) for (contingent) business interruption losses due to a failure of a critical infrastructure service although take-up and limits offered vary across countries. For example, in Australia, utility services disruption is usually included as a standard coverage in commercial property policies and is covered no matter the cause of the disruption – although sub-limits usually apply to this coverage (OECD, 2020[24]). In the United States, this coverage is usually only available as an endorsement and will often only trigger when the cause of the disruption is a peril covered under the property insurance policy (for example, a disruption to a utility service resulting from a flood or an earthquake might not be covered under a property insurance policy that excludes those perils) (IRMI, n.d.[163]).

Based on available data from Swiss Re sigma (available for the years 1990-2016), there were four major power disruptions, including a power outage in the US state of New Mexico in 2000 (approximately 1.3 million people lost power), the 2003 blackout in the Northeast United States and the Canadian province of Ontario (approximately 50 million people affected), a 2003 outage in almost all of Italy (approximately 55 million people affected) and a power outage in Barcelona (Spain) in 2007 (approximately 350 000 people affected). These four events led to an estimated USD 10.2 billion in economic losses (of which over 90% resulted from the 2003 blackout in the United States and Canada). Less than 10% of the economic losses were insured (also driven by low levels of insurance coverage for the 2003 blackout in North America). The available data only covers a small minority of major power disruptions and so economic losses from this risk are likely significantly higher.

Extreme weather-related events are often the cause of critical infrastructure disruptions, particularly for exposed distribution infrastructure such as electricity transmission towers. In the United States, for example, one study identified a significant increase in weather-related power outages across most regions over the last two decades (see Table A.1).

Table A A.1. Weather-related power outages: United States

	2000-2009	2010-2019
Northeast	127	329
Southwest	24	51
Southern Great Plains	42	88
Northwest	17	32
Southeast	209	282
Midwest	131	203
Hawaii and Puerto Rico	6	3
Northern Great Plains	2	2

Source: (Climate Central, 2020[164])

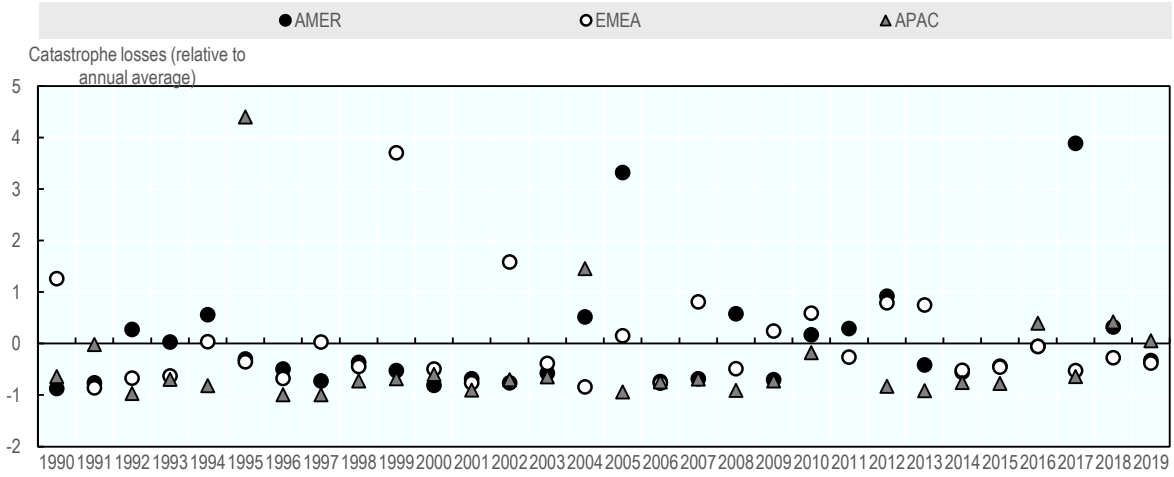
Loss correlation

Catastrophe perils, by definition, result in correlated losses within the area affected as many policyholders will face losses simultaneously from the same event. Diversification of insured exposures can be achieved

by providing coverage in different regions (within a country or internationally) where exposure to natural catastrophes is not correlated (i.e. in regions that are unlikely to face catastrophe losses simultaneously as the result of the same or a related event). Reinsurers achieve diversification by assuming risk in different countries around the world.

While some natural catastrophe events can impact large geographic areas within a country or region, it is unlikely[94] that a single or related set of natural catastrophe events will affect multiple regions of the world which allows insurers and reinsurers to achieve diversification by covering risks in different regions. Figure A.6 plots the level of annual catastrophe losses in OECD countries for three regions (Americas; Europe, Middle East, Africa; and Asia Pacific) relative to average annual losses in each region. There is little evidence that the occurrence of severe loss years is correlated across regions (i.e. that a severe loss year in Europe is correlated to a severe loss year in Asia-Pacific or the Americas) – in fact, the level of correlation over the last 30 years is less than 15% across the different regions. Given that there is little evidence of correlation across regions, insurers and reinsurers should be able to diversify their exposure to natural catastrophe risk in one region by assuming natural catastrophe risk in another.

Figure A A.6. Correlation in severe catastrophe loss years across regions



Source: OECD calculations based on data provided by Swiss Re sigma

Uncertainty in risk assessment/underwriting

Another factor that could influence the level of insurance coverage for catastrophe perils is the amount of uncertainty in estimating losses. As noted above, the low frequency of catastrophe events limits the availability of data on historical experience and therefore results in higher levels of uncertainty in estimates of expected losses – and usually higher premiums as insurers are likely to address uncertainty by charging higher prices for coverage (Kunreuther et al., 1995[165]).[95]

[94] As understanding of the climate and other physical drivers of extreme events has improved, some correlation has been observed in the occurrence of extreme events across different regions of the world. For example, one recent study has found a link between extreme precipitation events across different regions of the world as well as synchronisation in monsoonal rain patterns (Boers et al., 2019[281]).

[95] One 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 (Kunreuther et al., 1995[165]).

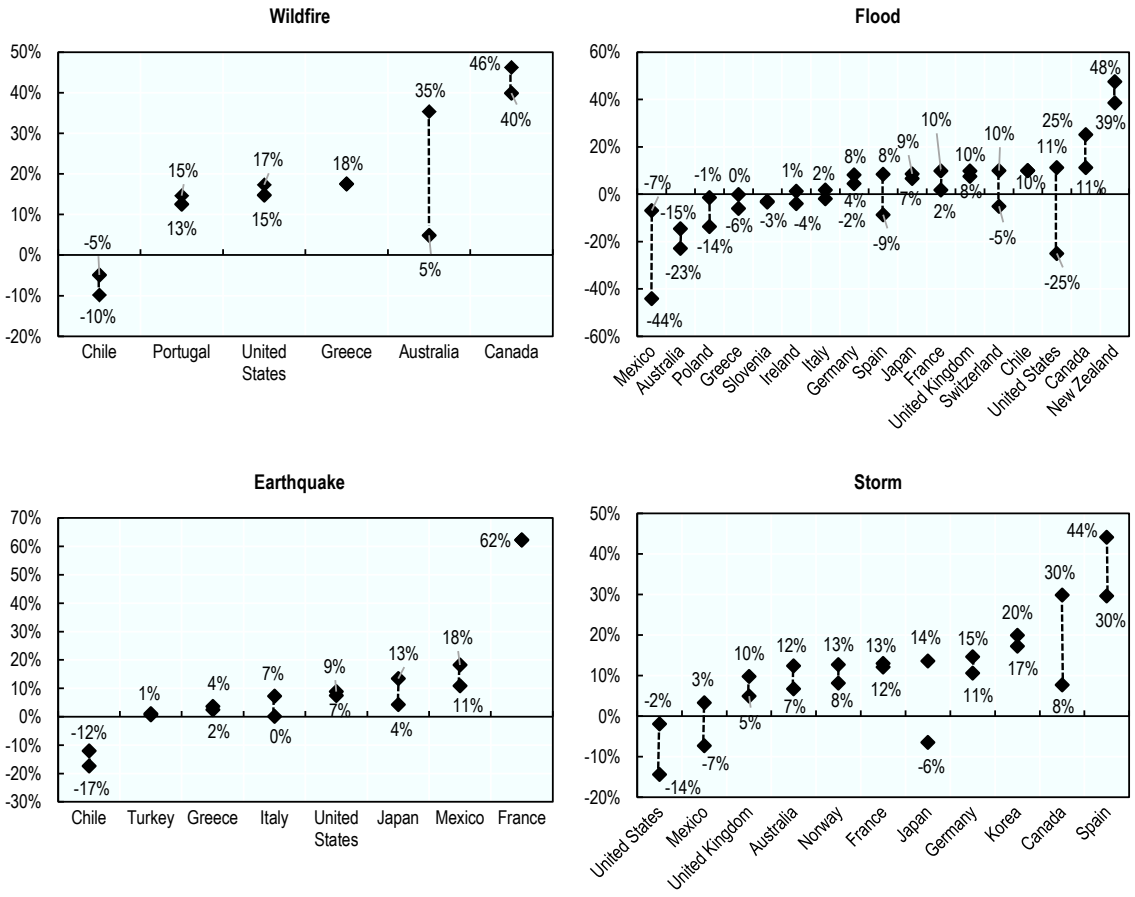
Catastrophe modelling approaches have been developed to address challenges related to the low frequency of catastrophe events. These models generate huge numbers of event scenarios to develop probabilistic estimates of potential losses which can be used to assess risk at specific locations and price insurance coverage. Models for natural catastrophe perils have existed since the 1990s and have expanded to cover the main perils across most OECD countries. Among catastrophe perils, modelling for natural catastrophes is the most advanced although some areas for potential improvement have been identified, including the need to incorporate a broader spectrum of losses (e.g. contingent business interruption, loss adjustment expenses) as well as modelling of "secondary perils" such as cyclone-induced flooding or tsunami following earthquake (Golnaraghi, 2018[166]), (PRA, 2020[167]). For example, in its feedback to insurers after a 2019 general insurance stress testing exercise, the UK Prudential Regulation Authority noted a gap between insurer-assessed (model-based) flood and tsunami losses after a US hurricane and Japanese earthquake (respectively) relative to actual flood losses after Hurricane Harvey and tsunami losses after the Tohuku earthquake and suggested these gaps were partly driven by different capacities for modelling these types of secondary perils (PRA, 2020[167]).

In addition, a changing climate creates challenges for modelling potential losses into the future. While the large catastrophe modelling firms employ leading scientists and make use of the latest research and climate modelling, there remains significant uncertainty in understanding future climate parameters – particularly for some perils such as tropical cyclones and in terms of understanding potential impacts at specific locations. Climate modelling techniques are improving and increasingly allow "downscaling" to the local level which could be leveraged to improve the ability of catastrophe models to integrate climate change into future model outputs (Golnaraghi, 2018[166]). The catastrophe modelling firms are also increasingly integrating forward-looking climate impacts into their models. For example, RMS has made a set of models for North Atlantic Hurricane, Europe Inland Flood and Europe Windstorm available that will allow users to adjust time horizons using the different future climate scenarios (RCPs) (RMS, 2021[168]). AIR Worldwide is examining the potential impacts of different climate scenarios on typhoon, wildfire, hailstorm, and coastal flood losses and has developed future event sets for key exposed regions such as Miami (Florida, United States) (AIR Worldwide, 2021[169]), (Churney, 2021[170]).

Insurability challenges

In the vast majority of OECD countries (for which sufficient data is available), the share of wildfire, flood, storm and earthquake losses that was insured increased in recent years relative to previous decades (i.e. 2010-2019 vs 1990-2009) – with a few exceptions. The share of wildfire and earthquake losses insured appears to have declined in Chile (although there was more limited data on catastrophe events in Chile). A larger number of countries appear to have experienced a decline in the share of flood losses insured between 2010 and 2019 relative to 1990-2009, including Australia, Poland, Mexico, Greece, Slovenia and likely Italy. In the United States, the share of storm losses insured apears to have declined (see Figure A.7).

Figure A A.7. Increase (decrease) in share of natural catastrophe economic losses insured (2010-2019 vs. 1990-2009)



Note: The charts show two estimates: (i) the change in the share of aggregate economic losses insured (2010-2019 relative to 1990-2009); and (ii) the change in average of the insured share of losses for each individual event (2010-2019 relative to 1990-2009). The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on data provided by Swiss Re sigma and PCS.

A number of governments and insurance supervisors have examined – or have taken steps to address – emerging insurability challenges for some natural catastrophe perils:

- In the United Kingdom, insurance companies have raised concerns about providing coverage for flood damage in high-risk areas for a number of years. Insurers had committed to provide insurance coverage for properties up to a specific level of flood risk and worked with government to encourage sufficient investment in flood risk mitigation to maximise the share of properties deemed insurable. In 2016, Flood Re was established to provide reinsurance coverage to insurers that cover high-risk properties with the aim of reducing the level of risk at those properties over time and ultimately returning to a risk-reflective market without cross-subsidy.
- In Ireland, insurers have reportedly refused to provide flood coverage (or substantially increased premiums) for residential (household) policyholders that have made a claim for flood damage and sometimes others deemed to be at high-risk of flooding. A parliamentary committee prepared a report on this issue in January 2016 that considered solutions such as improving a data sharing mechanism between insurers and the government on flood defence measures as well greater investment in flood risk reduction and restrictions on building in floodplains (amongst other possible

solutions) (Joint Committee on Environment, 2016[171]). Draft legislation that would prohibit insurers from discriminating based on past flood claims or unreasonably refusing to offer flood insurance coverage was introduced in 2016 although not enacted (McGrath, 2016[172]).

- In Canada, a federal ministry (Public Safety Canada) has reportedly established a task force involving the insurance industry to examine flood insurance issues including challenges in accessing coverage for high-risk residential (household) properties (Meckbach, 2021[173]).
- In Australia, concerns about the affordability of coverage for cyclone risk in northern Australia led to discussions on the potential establishment of a cyclone reinsurance pool to ensure the continued availability of affordable coverage (Crowe, 2019[174]) although there were differing views among stakeholders on how best to address insurability challenges.[96] On 4 May 2021, the Government of Australia announced plans to establish a government-backed reinsurance programme for cyclone wind and flood damage for residential (household) and small business policyholders in Northern Australia (Australia Treasury Ministers, 2021[117]).
- A number of large catastrophic wildfires in recent years have led to insurability challenges in the US state of California. Households in areas at high-risk of wildfire have faced premium increases and insurer-initiated non-renewals of coverage.[97] Between 2010 and 2018, the California Department of Insurance saw an increase of 573% in the number of complaints received related to renewal issues (usually non-renewal decisions by insurers) and 224% in complaints received related to premium increases from consumers residing in areas designated as having the highest fire risk (CDI, 2019[175]), (CDI, 2020[176]). In 2019, there was reportedly a 203% increase in the number of non-renewals for policyholders located in the 10 most exposed counties in California (Jergler, 2020[177]). In response, the California Department of Insurance has imposed moratoriums on non-renewals (California Department of Insurance, 2019[178]) (Insurance Journal, 2020[179]) and held a virtual investigative hearing in October 2020 aimed at finding a solution to the challenges in the insurance sector (Jergler, 2020[177]). In the US state of Oregon, the Insurance Commissioner issued a Wildfire Emergency Order in September 2020 prohibiting insurers from cancelling or not renewing a policy for the duration of the order in a list of designated areas impacted by wildfires (Oregon Department of Consumer and Business Services, 2020[180]). Unlike other states, the residual insurance arrangement in California has seen an increase in sum insured in recent years (84% between 2013 and 2019) (III, 2020[181]) (see Box A.6). In addition, the California Earthquake Authority has been appointed as the administrator of a public fund to pay liability claims against public electric utilities related to the role of their transmission lines in igniting destructive fires (CEA, 2020[182]).
- There are also recent reports of insurability challenges related to hurricane (wind) coverage in the US state of Florida, including reports of non-renewals by insurers (Insurance Journal, 2018[183]), requests for regulatory approval of large premium rate increases (O'Connor, 2020[184]) and an increase in policy count in 2020 at Citizens (the residual arrangement) (Saunders, 2020[185]) that has reportedly accelerated in 2021 (O'Connor, 2021[186]). The challenges are reportedly caused by increasing litigation related to non-catastrophe water damage and increasing costs for reinsurance coverage (O'Connor, 2020[187]).

[96] One area of focus has been on risk mitigation, both in terms of large-scale mitigation infrastructure and property-level measures. The Insurance Council of Australia has reportedly provided a list of priority mitigation project in Northern Australia that would reduce some of the pressure on premium affordability by reducing expected losses (Insurance News Australia, 2021[310]).

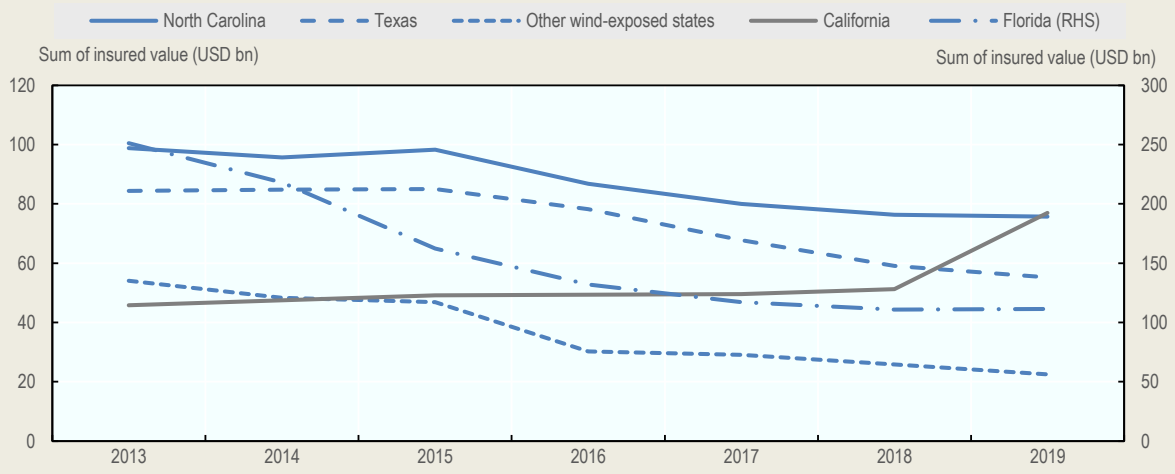
[97] Some insurers have also reportedly begun applying wildfire exclusions to general liability policies as a result of concerns over potential claims against companies or their products for any role in the ignition of destructive wildfires (Divelbiss and Laun, 2020[280]).

Box A A.6. US residual insurance markets

In many US states, residual insurance markets have been established to provide insurance coverage to residential (household) and sometimes commercial policyholders that cannot access insurance coverage at a reasonable cost from private insurers. In most states, the residual markets aim to play the role of insurer of last resort by ensuring that the premiums they charge are higher than the private market and by taking regular steps to transfer insurance policies back to private insurance companies (often referred to as "depopulation"). In hurricane-exposed states, the residual plans may focus on storm (wind) only coverage (referred to as beach and wind pools). Given this role, changes in residual plan insured exposure may provide some insight into the availability of affordable catastrophe peril coverage in private markets (e.g. a decrease in residual plan policy count or insured exposure might indicate that more policyholders are able to find affordable coverage in the private market – assuming that the policyholders withdrawing from the residual plan are finding coverage in the private market and not becoming uninsured).

In the United States, the insured exposure of residual insurance arrangements for wind coverage has declined in recent years suggesting that the private insurance market is providing affordable coverage for most wind risks in the United States (although challenges in the Florida market may only become apparent in 2020). The US state of California residual plan has seen a significant increase in insured exposure since 2018 (despite concerns over the comprehensiveness of California residual plan coverage)[1] although residual plans in the states of Washington and Oregon have seen stable (or declining) insured exposure.

Figure A A.8. Insured exposure: selected US residual insurance arrangement



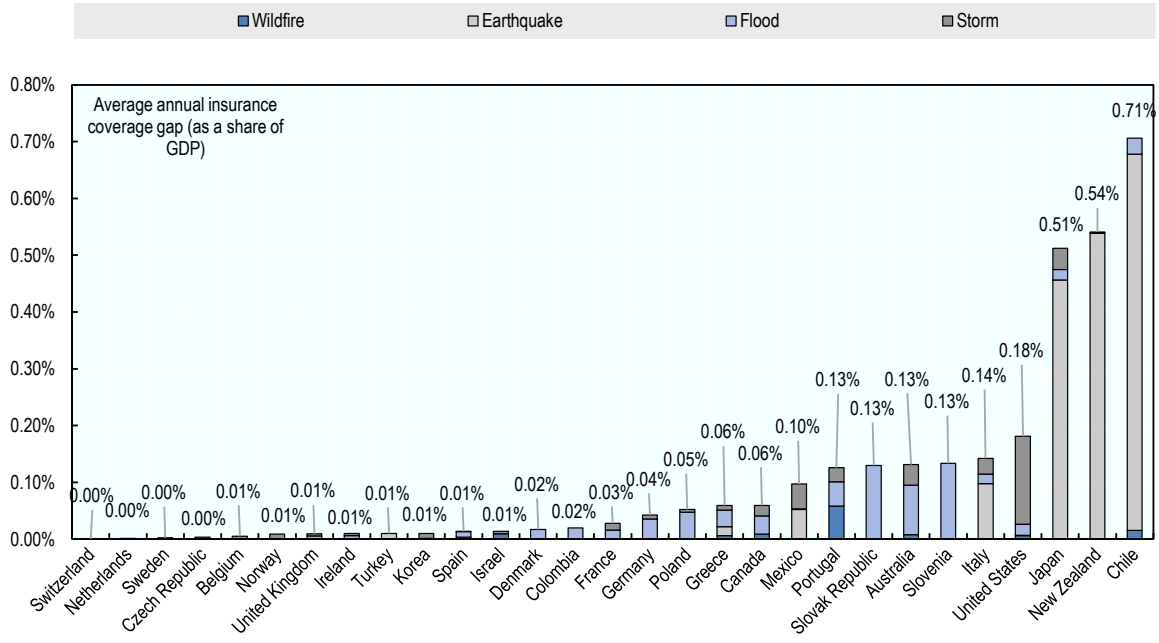
Note: "Others" includes Alabama, Mississippi, South Carolina, Georgia and Louisiana. Florida, Georgia and Louisiana are FAIR plans – others are beach and wind pools.
Source: (III, 2020[181]) (based on data collected by the Property Insurance Plan Service Office).

[1] In California, the residual plan only provides standard coverage for fire and optional coverage by endorsement for wind, hail, explosion, riot and some other perils. Coverage for household liability and additional living expenses is not available (Barlow, 2020[188]).

Potential cost of limiting underinsurance for natural catastrophes

Figure A.9 provides some estimates of the magnitude of the insurance coverage gap for natural catastrophe perils across OECD countries as a share of GDP, calculated as the gap between average annual economic losses and average annual insured losses for each peril (for the period 2010-2019).

Figure A A.9. Average annual natural catastrophe insurance coverage gap



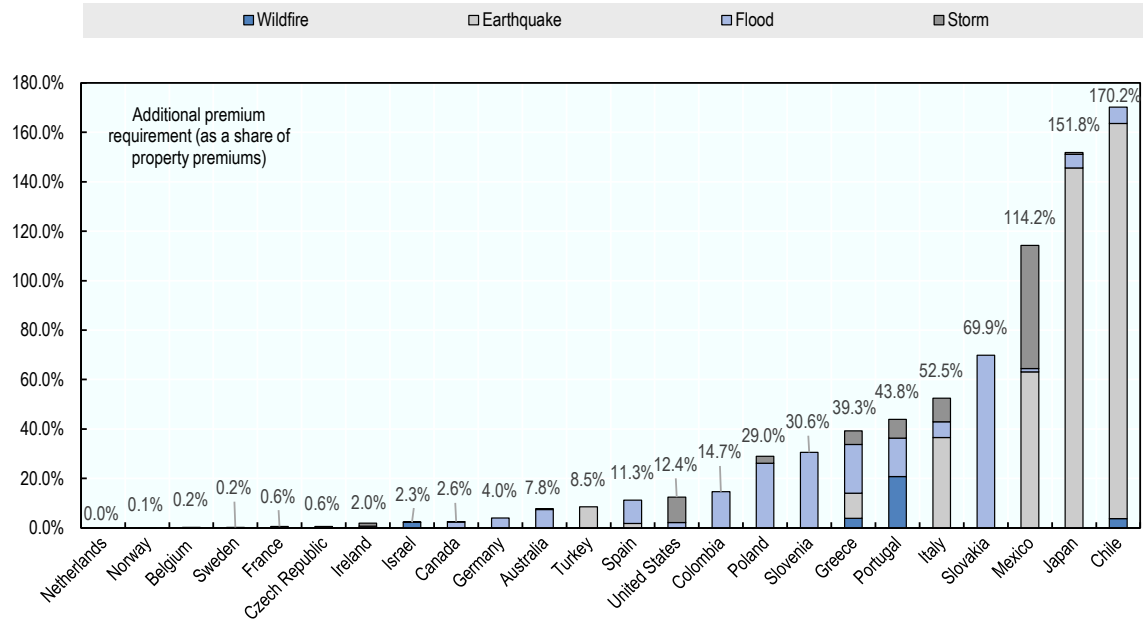
Note: The insurance coverage gap is calculated as the difference between average annual economic losses and average annual insured losses (2010-2019) as a share of GDP (average annual level in USD millions for 2010-2019). The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based data provided by Swiss Re sigma and PCS and data on GDP from (OECD, 2020[4]).

Figure A.10 provides some estimates of the amount of additional premiums that would need to be collected by insurers across OECD countries (as a share of property insurance premiums) to provide a high-level of protection for natural catastrophe risks. The estimates assume that a high-level of protection would be achieved if 70% of annual average economic losses (based on 2010-2019 losses) were insured as even the countries with the highest levels of insurance coverage for catastrophe perils incur uninsured losses of approximately 30%.[98] The estimates are also adjusted to incorporate a loss ratio similar to other non-life lines of business (65%). For most countries, insurers would need to collect less than 10% more in premium than they do currently to achieve a high-level of insurance coverage for catastrophe perils. In Australia and the United States, the estimated additional premium requirement would be higher (15% and 21%, respectively) driven by insurance coverage gaps for storm and flood losses. In Chile, the large additional premium requirement is mostly driven by uninsured losses related to the devastating earthquake in 2010. In other countries, including Colombia, Poland, Slovenia, Greece, Portugal, Slovakia, Italy and Mexico, the higher levels of estimated additional premium requirements is likely linked to lower levels of property

[98] Even if insurance coverage of private assets is near 100%, uninsured damages and losses may be incurred by public sector entities or may result from the application of deductible or other co-insurance conditions.

insurance penetration more generally (see Figure A.2) as well as large losses in the cases of Italy and Mexico.

Figure A A.10. Estimated additional annual premium needed to address natural catastrophe insurance gaps



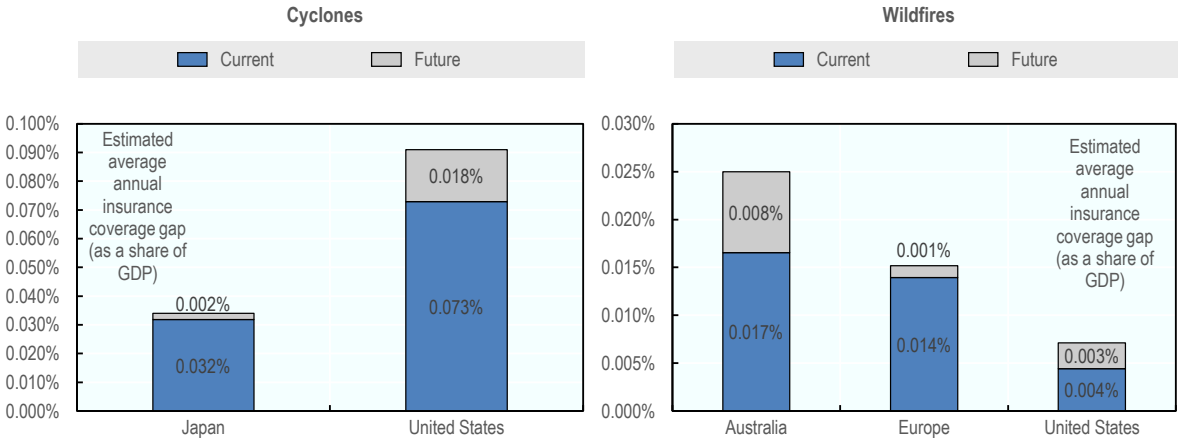
Note: The calculation was made by dividing the difference between 70% of average annual economic losses (2010-2019) and average annual insured losses (2010-2019) (by peril) by 65% (to account for a normal loss ratio) and then by the amount of property insurance premium collected in 2018. The data for Japan includes both Japanese private and mutual insurers although data from mutual insurers for individual events (particularly smaller events) is not always available. As a result, some underestimation of insured losses in Japan is possible.
Source: OECD calculations based on (OECD, 2020[189]) and data provided by Swiss Re sigma and PCS.

As noted above, future loss levels may increase as a result of a changing climate (as well as due to increases in the value of exposed assets). Figure A.11 provides some estimates of the potential magnitude of the insurance coverage gap that could emerge as a result of higher losses due to more intense cyclones and longer fire seasons in selected countries. For cyclones, the estimates were generated by assuming a constant frequency of cyclone events but a higher share (10%)[99] of severe cyclones relative to the period 1990-2019 for Japan and the United States. The wildfire estimates were generated by calculating the average monthly loss from wildfires over 1990-2019 and adding an additional month of losses in Europe (Greece, Portugal and Spain), two additional months of losses in the United States and three additional months of losses in Australia based on projections of future increases in fire season duration.[100] The insurance coverage gap is presented as the difference between average annual economic losses and average annual insured losses as a share of GDP, with adjustments to the magnitude of economic losses based on a potential increase.

[99] The 10% increase in the proportion of intense cyclones is based on as estimate referenced in (Bruyère et al., 2019[283]). The estimate is actually for the Southern hemisphere where most studies suggest that increases in intensity will be lower (therefore providing a conservative estimate).

[100] The fire season extensions are based on (Four Twenty Seven, 2020[161]).

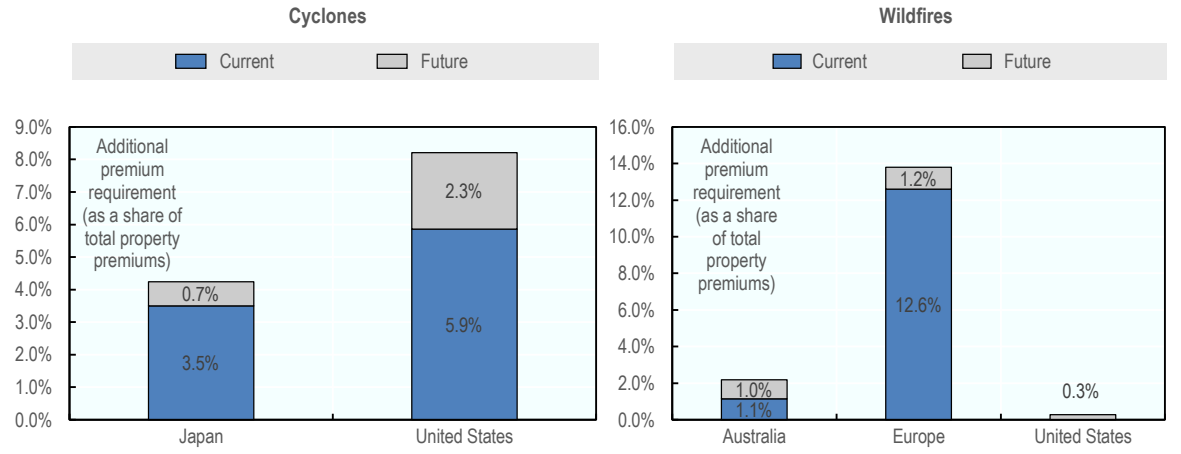
Figure A A.11. Estimated additional annual insurance coverage gap due to cyclones and wildfires (selected countries)



Note: The insurance coverage gap is calculated as the difference between average annual economic losses and average annual insured losses (2010-2019) as a share of GDP (average annual level in USD millions for 2010-2019). The calculation of future additional average annual economic loss estimates are based on a loss distribution that included a 10% higher proportion of intense cyclones and longer fire seasons.
Source: OECD calculations based data provided by Swiss Re sigma and PCS and data on GDP from (OECD, 2020[4]).

Figure A.12 provides some estimates of the potential additional premium requirement to address losses from more intense cyclones and longer fire seasons in selected countries (i.e. the potential **future** premium requirement to address future underinsurance in addition to the **current** estimate of needed additional premium to address underinsurance) – based on the same increase in potential losses as described above. The estimated additional premium requirements were calculated as in Figure A.10 (i.e. taking into account normal loss ratio levels and comparing the total to 2018 property premium amounts). While the methodology is less than ideal, the estimates suggest that a changing climate might not add a significant amount of additional premium requirement, at least in the near term.

Figure A A.12. Estimated additional annual premium needed to address cyclone and wildfire insurance gaps (changing climate)



Note: The calculation of current additional premium requirement was made by dividing the difference between 70% of average annual in economic losses (2010-2019) and average annual insured losses (2010-2019) (by peril) by 65% (to account for a normal loss ratio) and then by the amount of property insurance premium collected in 2018. The calculation for future additional premium requirement was similar although based on average annual economic loss estimates for a loss distribution that included a 10% higher proportion of intense cyclones and longer fire seasons.
Source: OECD calculations based on (OECD, 2020[189]) and data provided by Swiss Re sigma and PCS.

Annex B. Cyber risks

The digital transformation of the economy has led to new risks and new insurance coverages to protect against those risks. Cyber risk refers to the broad range of incidents - whether intentional or unintentional, malicious or accidental - that could lead to a compromise of the confidentiality, integrity and/or availability of information and information systems and result in losses to those dependent on that information and those information systems. Cyber insurance coverage has been developed to address (some) of these losses, either in stand-alone cyber insurance policies or through expansions to the scope of coverage in other types of property/business interruption or liability policies (sometimes unintentional).

While the market has grown rapidly, there remains a significant level of uninsured losses resulting from: (i) low levels of take-up and coverage; and (ii) potentially significant gaps in coverage (discussed below). As highlighted in previous OECD reports on cyber insurance (OECD, 2020[190]), the take-up by businesses of (affirmative) cyber insurance coverage – while increasing quickly – has been below levels for other types of commercial insurance coverage. There is some evidence that this gap in take-up is declining. An annual survey of risk managers from around the world (with 78% of respondents from the United States and 10% from Europe) found that the share of companies that buy cyber insurance has increased to 78% in 2020, from approximately 35% in 2011 when the survey was first distributed (with approximately 55% acquiring that coverage in a stand-alone cyber insurance policy) (Advisen and Zurich North America, 2020[191]). However, another recent survey focused on stand-alone cyber insurance purchase found much lower levels of take-up:, 33% of surveyed companies in the United States, 30% in Belgium, 28% in Germany, 27% in France, 26% in the United Kingdom and Spain and 21% in Ireland and the Netherlands (Hiscox, 2021[192]). Some past surveys have also found a large gap in take-up of cyber insurance between large and small firms (large firm take up rates were 2x or 3x higher than small firms) (Hiscox, 2018[193]).

Insured limits for cyber insurance policies are significantly lower than for other types of commercial policies (particularly property insurance which normally provides insured limits of USD 1 billion or more for large companies). In the US market (normally considered the most developed cyber insurance market), the average cyber insurance limit purchased across all of one broker's clients was USD 21.3 million in 2019 – and USD 65.3 million among large clients (i.e. those with more than USD 1 billion in annual revenues) (Marsh, 2020[194]). Another analysis of cyber insurance limits estimated that approximately 750 companies worldwide had cyber insurance limits of USD 100 million – and only 40 companies had limits of more than USD 500 million (see Table B.1). As discussed below, lower insured limits are at least partly a result of insurers' efforts to limit their exposure (although policyholders may also not be seeking significantly higher limits).

Table A B.1. Estimates of insured limits and premiums

Insured limit	Number of companies	Aggregate premium	Share of total premiums
>USD 500 million	40	USD 250 million	5%
USD 300-499 million	60	USD 300 million	5%
USD 200-299 million	150	USD 600 million	11%
USD 100-199 million	500	USD 1.4 billion	26%
USD 35-99 million	1 100	USD 1.5 billion	27%
<USD 35 million	Unknown	USD 1.4 billion	26%

Source: PCS estimates based on PCS Cyber RLM and internal research, reported in (Johansmeyer, 2020[195])

Data on insured losses resulting from cyber incidents is not systematically collected although some loss aggregation companies have begun collecting insured loss data for significant events. The US National Association of Insurance Commissioners collects annual data on cyber insurance premiums and claims which can allow for an estimate of insured cyber losses. For 2018, the top 20 largest insurers (for stand-alone cyber insurance – accounting for 94% of the market)[101] paid approximately USD 366.5 million in claims for USD 1.05 billion in collected premiums (NAIC, 2019[196]).[102] Assuming a total global market of approximately USD 6.7 billion in premiums – and a similar loss experience for other insurers – this would equate to approximately USD 2.3 billion in insured cyber losses in 2018.

There are a variety of estimates of the annual economic losses resulting from cyber incidents (or various components such as cyber crime or ransomware) although few official sources (see discussion below). In the case of cyber crime, some law enforcement agencies publish specific data on loss impacts of reported cyber crime. In the United States, the Federal Bureau of Investigation publishes data on complaints to the Internet Crime Complaint Center (IC3), including the number of reported incidents and estimated losses. In 2018, IC3 received just over 350 000 complaints with reported losses of USD 2.7 billion. Based on an assumption that most cyber crimes are reported (which may not be the case) – and an estimate that cyber crime accounts for 95% of claims payments (NetDiligence, 2019[197])[103] – the share of cyber losses insured in the United States in 2018 may have been as low as 14%.[104] There is also some data available on insured losses (and estimated economic losses) for specific large cyber events. For example, the WannaCry and NotPetya attacks of 2017 are estimated to have resulted in more than USD 10 billion in economic losses, of which approximately 30% - 35% were insured (Brew, 2020[198]).[105] Equifax was covered for approximately USD 125 million of the more than USD 1 billion in losses that it faced as a result of a major data breach.[106]

Potential drivers of underinsurance for cyber risk

Form of coverage

As discussed elsewhere (see (OECD, 2020[190])), the cyber insurance product has developed (in part) as a result of the application of cyber-related exclusions in other types of insurance policies. For example, in the United States where data protection requirements (and related consumer litigation) were first

[101] The NAIC also collects data on cyber insurance provided through package policies, which accounted for approximately 45% of report cyber insurance premium. However, the estimates of cyber premium and claims payments for package policies involve greater uncertainty given the challenges in assigning premiums between the cyber and non-cyber coverages in the policy. As a result, only stand-alone cyber insurance premiums and claims were used for the purposes of this estimate.

[102] OECD calculations based on published written premiums and loss ratios for the largest 20 stand-alone cyber insurers.

[103] NetDiligence publishes an annual study on claims paid by insurers in the United States and elsewhere. For the 2018 data year, the study estimates that 95% of claims payments were related to incidents that can be classified as criminal (NetDiligence, 2019[197]).

[104] Calculated as USD 389.9 million in paid claims according to NAIC data (336.5/0.94 (market share)) divided by 2 842 million (2 700/0.95 (crime share)).

[105] Including estimates provided by PCS of insured losses under both affirmative and non-affirmative coverage for cyber risks. .

[106] Based on data provided by PCS.

established, insurers began applying exclusions for privacy-related breaches in general liability policies which led to the development of specific coverage for this type of liability in cyber insurance policies. Coverage for cyber-extortion (ransomware) and cyber-fraud was included in cyber insurance policies as an alternative to the coverage provided in kidnap and ransom and crime policies as these policies had not been developed with these kinds of risks in mind. Business interruption coverage was included in cyber insurance as most cyber incidents would not meet the physical damage requirement that is often in place as a trigger for business interruption coverage in property insurance policies. As a result, there has been (and remains) some confusion among policyholders on where to find coverage for cyber-related risks as not all "traditional" insurance policies provide clarity on whether cyber risks are covered (OECD, 2020[190]). This lack of clarity has likely been a significant driver of underinsurance for cyber risk (along with a lack of cyber risk awareness among policyholders and limited investment by some companies in understanding their exposures to cyber risk).

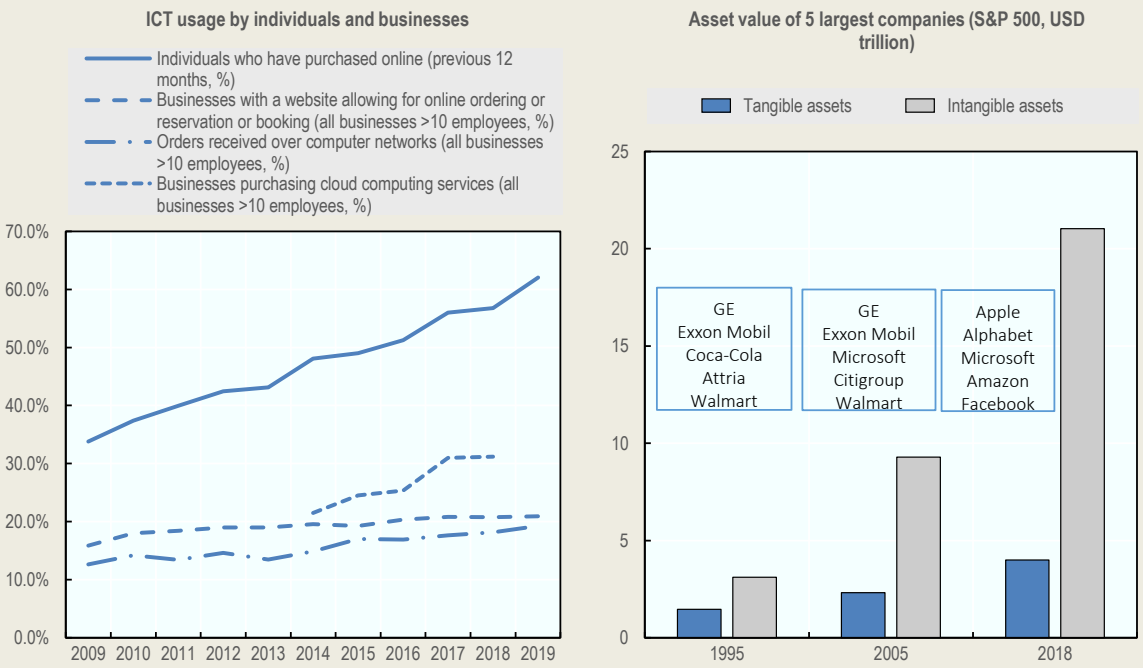
Loss magnitude

Estimates of the potential magnitude of economic losses from cyber incidents are huge although there is little clarity on the actual level of losses that would fall within the scope of existing (or potential) cyber insurance coverage. Digitalisation will clearly increase future potential cyber loss magnitudes due to continued growth in activities and assets that are exposed to losses as a result of a cyber incident (whether malicious or unintentional) (see Box B.1). While more recent data is not yet available, the COVID-19 health crisis has likely accelerated the rate of digitalisation.

Box A B.1. Digital transformation of economic activities

An increasing share of economic activity is taking place online as individuals make an increasing share of their purchases online, more businesses provide an online option for placing orders or making reservations and bookings and increasing numbers of businesses make use of cloud services as part of their information technology infrastructure. At the same time, an increasing share of the largest companies' asset values is accounted for by intangible assets (including digital assets) (see Figure B.1).

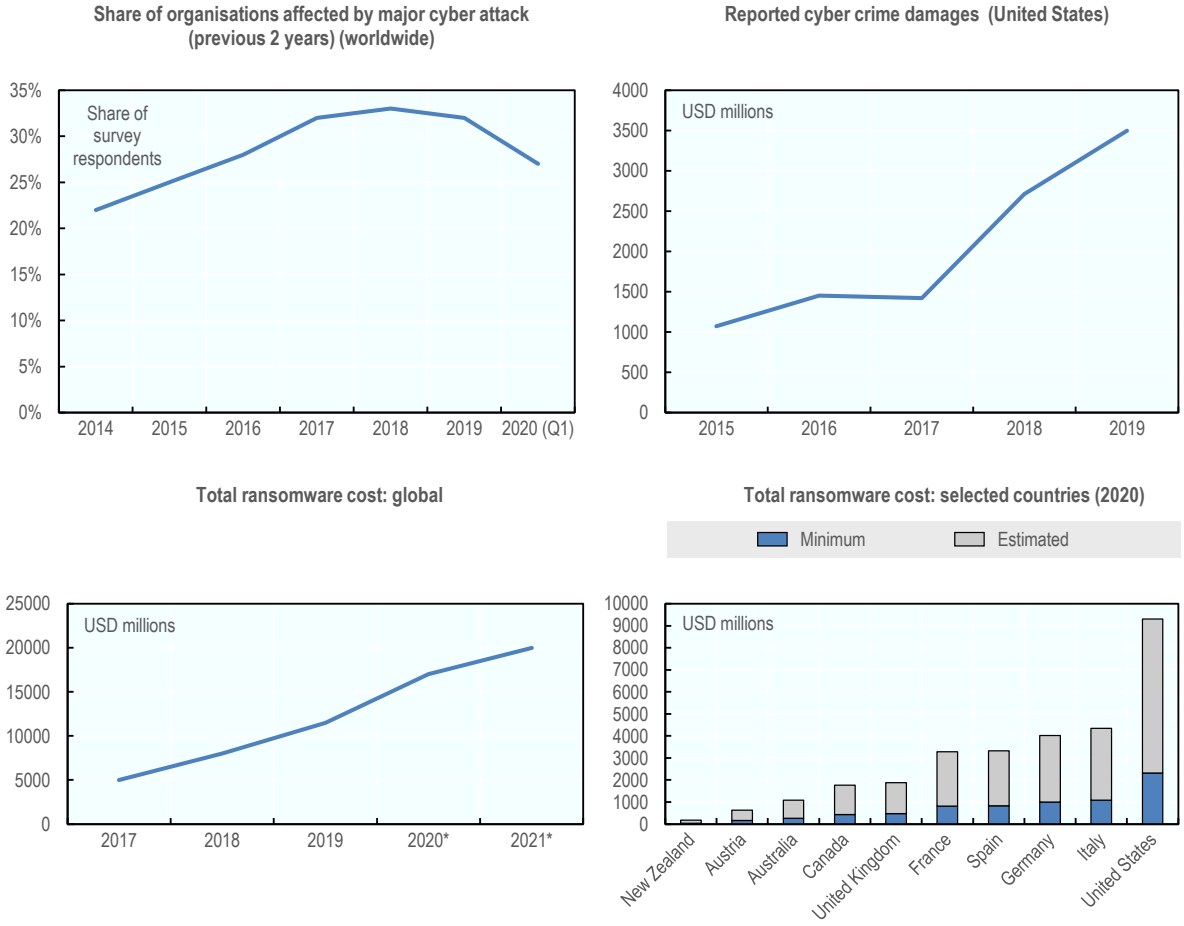
Figure A B.1. Indicators of digitalisation in OECD countries



Source: (OECD, 2020[199]), (OECD, 2020[200]), (Aon and Ponemon, 2020[201]).

There are a variety of reports that provide estimates of the cost of various types of incidents. Figure B.2 provides data from various sources on the increasing share of organisations that are affected by major cyber attacks, increased damages from reported cyber crimes (United States) and estimates of the increasing annual cost of ransomware over time (along with a breakdown of estimated ransomware costs by country).

Figure A B.2. Cyber attack trends



Note: For share of organisations affected, 2020 data is up to March only. For total ransomware cost globally, data for 2020 and 2021 are projections. For total ransomware costs by country, the estimates are based on information submitted to a ransomware identification service (ID Ransomware).The minimum cost estimate assumed that 50% of the submissions were related to ransomware attacks on households with limited financial impact. The estimated cost is based on an assumption that only 25% of ransomware attacks are reported to the ransomware identification service.
Source: Top left: (Statista, 2020[202]); Top right: (Internet Crime Complaint Center (IC3), 2020[203]); Bottom left: (Safety Detectives, 2020[204]); Bottom right: (Emsisoft, 2020[205]).

The transition to remote working in 2020 (which may lead to a longer-term shift) has likely increased losses from cyber incidents as attackers gain access to more points of entry into corporate networks via often less secure[107] home networks. There were numerous reports of an increasing number of cyber attacks during the first half of 2020. The FBI's IC3 has reportedly received 3 000 to 4 000 complaints per day since the beginning of the COVID-19 pandemic (compared to 1 000 per day previously) (Walter, 2020[206]) while the presence of ransomware on networks has reportedly increased by 72% to 105% (Gewirtz, 2020[207]).

In addition to a potential increase in losses from cyber fraud and extortion, business interruption and privacy breaches, increasing use of connected operational technologies could potentially lead to property damage as a result of a cyber attack. Operational technologies refer to the hardware and software that

[107] One recent analysis of a large sample of US networks for the presence of malware found that home office networks were 3x more likely to have at least one malware infection (relative to corporate networks) and had a 20x larger malware population for some types of malware than corporate networks (BitSight, 2020[276]).

increasingly monitor and control physical devices such as valves and pumps and whose compromise could potentially lead to physical damage or bodily injury (Coble, 2019[208]) (and which may not be covered by any type of insurance – see below). There have been a few reported incidents of physical damage resulting from remote access to operational technologies, including damages resulting from blast furnace failures at a steel mill in Germany in 2014 (Zetter, 2015[209]). There has also been at least one instance of a disruption to power infrastructure in the Ukraine as a result of a cyber-attack (Zetter, 2016[210]). The Centre for Risk Studies at the University of Cambridge has developed a number of scenarios that highlight some of the potential areas where a cyber-attack could lead to physical damage, including attacks involving laptop battery fires and connected building control systems (CCRS, 2020[211]).

Loss correlation

Unlike natural catastrophes, cyber risk cannot be diversified geographically as policyholders in different countries and regions can be simultaneously affected by the same underlying cyber incident. As a result, insurers aim to achieve diversification in the risks that they assume by building a portfolio of policyholders comprising businesses of different sizes, countries and sectors with moderate insured limits (Gallin, 2020[212]) – although some have suggested that this strategy has not achieved diversification for some types of attacks such as ransomware (Brew, 2020[198]). Some past cyber attacks (such as WannaCry and NotPetya) have affected companies of all sizes in different countries and across all sectors of the economy. Within a few days, WannaCry had already infected an estimated 200 000 victims in over 150 countries (Reuters, 2017[213]).

There are a number of potentially catastrophic (and technically-feasible) cyber risk scenarios that could result in major losses affecting many policyholders of different sizes in different sectors:

- A broadly-targeted ransomware attack, not unlike WannaCry, could potentially lead to losses across a large number of businesses. One scenario involving the spread of malware through phishing emails is calibrated based on the infection of 43.1% to 97.3% of all global devices resulting in potential economic losses of USD 85 billion to USD 193 billion, depending on the severity of the attack (Cambridge Centre for Risk Studies, Lloyd's of London and Nanyang Technological University, 2019[214]).
- A disruption to core digital infrastructure such as a major cloud service provider or another type of information technology managed service provider could lead to business interruption losses among a large number of policyholders simultaneously (the market for public cloud infrastructure-as-a-service and platform-as-a-service, for example, is highly concentrated (IDC, 2020[215])). One scenario involving a disruption to one of the top three cloud service providers for 3-6 days estimates economic losses among US clients of the provider of USD 6.9 billion to USD 14.7 billion (Lloyd's and AIR Worldwide, 2018[216]).

Uncertainty in risk assessment

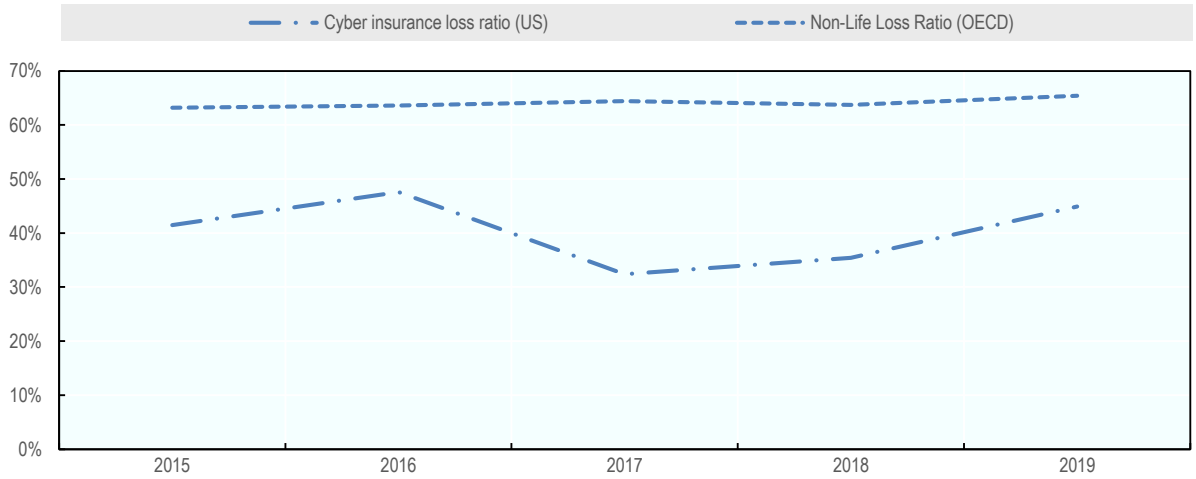
The capacity of insurance companies to assess cyber risk is challenged by a number of factors, including: (i) limited historical data due to the relatively recent emergence of cyber as a risk and low levels of incident reporting; (ii) evolutions in attack methods and security practices; and (iii) difficulties in understanding effective cyber security practices (OECD, 2017[217]). A number of catastrophe modelling tools have been developed for cyber risks although most are new and relatively untested (OECD, 2020[218]).

In its feedback to insurers participating in its annual general insurance stress test, the UK Prudential Regulation Authority identified significant variation in the capacity of insurers to assess potential losses from a prescribed ransomware scenario including different assumptions regarding losses related to non-affirmative coverage and significant differences in assumptions related to assessing revenue losses at affected policyholders and other related (non-business-interruption) costs (PRA, 2020[167]).

Insurability challenges

Cyber insurance has generally been a profitable line of business with low loss ratios relative to other types of coverage (approximately 40% on average since 2015 in the United States, relative to 64% for the non-life sector across OECD countries – see Figure B.3). Low loss ratios would normally suggest opportunities for market growth and for expanding available insurance coverage.

Figure A B.3. Cyber insurance loss ratios



Source: (OECD, 2021[219]) for non-life insurers, (Aon, 2020[220]) for cyber insurers.

However, there are some signs of recent capacity constraints. One recent survey of corporate risk managers, brokers and insurance companies from around the world found that most expected demand for cyber insurance and prices to increase (75% and 74%, respectively) although only 45% expected an increase in the supply of cyber insurance (Willis Re, 2020[221]). Pricing is reportedly increasing significantly (Aon, 2020[220]) (although in the context of general market hardening across most lines of business) with some reports that price increases are particularly focused on policies with high limits (Brew, 2020[198]). In the first quarter of 2021, cyber insurance rates rose an estimated 35% in the United States and 29% in the United Kingdom (while there was a moderation in price increases across most other commercial insurance lines) (Marsh, 2021[222]). According to one report, direct loss ratios for stand-alone coverage increased sharply in the United States to 73% in 2020 and to 105% in Canada (from 39% in 2019) (Fitch, 2021[223]).

As noted above, limits applied to cyber insurance policies are much lower than for other lines of business. Cyber insurers also appear to make significant use of reinsurance, potentially more than in other lines of business (one estimate suggests that 40% of premiums are ceded to reinsurers (Johansmeyer, 2020[195])) although most reinsurance support continues to be provided on a proportional basis with limited appetite for excess-of-loss reinsurance arrangements (according to one reinsurance organisation, reinsurers are aiming to address this constraint through new product development and increased capital investment). Some reinsurance support is reportedly being withdrawn for some smaller cyber insurers in response to increasing losses (Brew, 2020[198]).

Some specific elements of cyber insurance coverage are (or may become) more challenging to address, including nation-state and other politically-motivated attacks, ransomware, property damage resulting from cyber-attack and infrastructure disruptions.

The involvement of nation-states and other politically-motivated actors in propagating cyber attacks creates a number of challenges, including:

- The treatment of politically-motivated attacks across other lines of business: Many cyber insurance policies include coverage for cyber attacks by nation-states, terrorist organisations and other politically-motivated actors (often as a write-back to narrow the scope of a general war or terrorism exclusion) although other types of polices (such as property insurance) usually exclude any losses due to war or terrorism (OECD, 2020[24]). As a result, losses resulting from politically-motivated attacks might only be covered if cyber coverage is secured in a stand-alone cyber insurance policy (although the applicability of war exclusions to nation-state cyber attacks is thus far untested[108]).
- The potential capability of nation-state actors to cause more severe damages and losses: Nation-state actors are generally considered to have much more advanced cyber attack capabilities than cyber criminals or other types of politically-motivated actors such as terrorist organisations, including the capability to execute highly-disruptive and destructive[109] cyber attacks (Cambridge Centre for Risk Studies, 2017[224]).

There are efforts to address the insurance implications of nation-state and other politically-motivated cyber attacks. Terrorism (re)insurance programmes in most countries are examining whether their programmes would respond to a cyber-terrorism attack and some have taken steps to provide clarity and/or address impediments to providing coverage although programmes in some countries (e.g. Australia) are limited by legislation from providing coverage (OECD, 2020[24]). The Lloyd's market has established a working group to develop a cyber war exclusion clause[110] (LMA, n.d.[225]). The Geneva Association and the International Forum of Terrorism Risk (Re)Insurance Pools (IFTRIP) have collaborated on the development of a definition of "hostile cyber activity" (i.e. nation-state-linked cyber attacks short of war) that could potentially be used to provide clarity on insurance coverage of these types of politically-motivated attacks in the future (Carter and Enoizi, 2020[226]).[111]

Consistent with the recommendations developed in recent OECD work (OECD, 2020[190]) – and in response to a significant increase in ransomware attacks in 2020 – the G7 Finance Ministers and some individual governments (e.g. United States) have reconfirmed that ransom payments (including insurance reimbursements of ransom payments) are financial activities to which anti-money laundering, combating the financing of terrorism and sanctions policies apply (G7, 2020[227]) (Office of Foreign Assets Control, 2020[228]). While these requirements are not new, the reconfirmation could be a signal of future enforcement action in this area which could potentially impact the future insurability of ransomware losses. For example, victims and their insurers may become more cautious about making ransom payments if there is

[108] Damages resulting from conflict between nation-states are generally considered uninsurable and excluded from coverage although some war exclusions are only applicable in the case of war between any of the "Five Powers" (China, France, Russia, United Kingdom, United States). The applicability of war exclusions to specific losses has been subject to a number of disputes and litigation over the years – and is currently being tested in the context of a nation-state cyber attack through a dispute between Zurich Insurance and Mondelez over losses that resulted from the NotPetya cyber attack in 2017.

[109] A number of disruptive attacks have been attributed to nation-state actors, including the NotPetya and WannaCry attacks and disruptions to the electricity grid in the Ukraine (OECD, 2020[24]).

[110] A recent webinar session provided an overview of the proposed clause which would aim to exclude losses from a cyber attack undertaken in the context of a conflict involving the use of physical force by one state against another as well as the use of cyber-attacks as a retaliatory measure.

[111] This group is also developing reports on attribution of cyber attacks and the loss potential of "hostile cyber activity" (Carter and Enoizi, 2020[226]).

uncertainty related to the source of the attack which could potentially lead to higher costs (and therefore higher premium requirements).[112]

Cyber insurance policies have not generally provided coverage for property damage, with the exception of some coverage for computer hardware damaged as a result of a cyber attack ("bricking"). However, some coverage for this risk has been available through property insurance policies that provide coverage for fire or explosion no matter the proximate cause (in some cases as non-affirmative or silent coverage). However, according to some market participants, insurers have been increasingly applying cyber exclusions to property insurance policies that could eliminate this coverage – without any grant of property damage coverage in cyber insurance policies (one recent survey found the share of cyber underwriters offering coverage for physical damage declined in 2020 relative to previous years) (Advisen and PartnerRe, 2020[229]). The effort to provide clarity on coverage for cyber risks across all lines of business (encouraged, in some cases, by insurance supervisors and the OECD) as well as the potential for significant property damage losses to result from cyber incidents affecting connected operational technologies may be driving insurers to exclude this coverage from property insurance policies.

Unlike property insurance policies,[113] cyber insurance policies do not often provide (contingent) business interruption coverage for utility failures (e.g. disruptions to power, telecommunications or access to the internet) – reportedly driven by exclusions applied by reinsurers who deem widespread disruptions to the internet or networks to be uninsurable (Gallin, 2020[212]).

Potential cost of limiting underinsurance for cyber risk

Figure B.4 provides some rough estimates of the magnitude of the insurance coverage gap for cyber risks as a share of OECD GDP, calculated as the gap between average annual economic losses and average annual insured losses currently and in the next decade based on projected rates of growth in losses. Given the lack of historical data on cyber losses (insured and uninsured), a number of assumptions were made to generate these estimates:

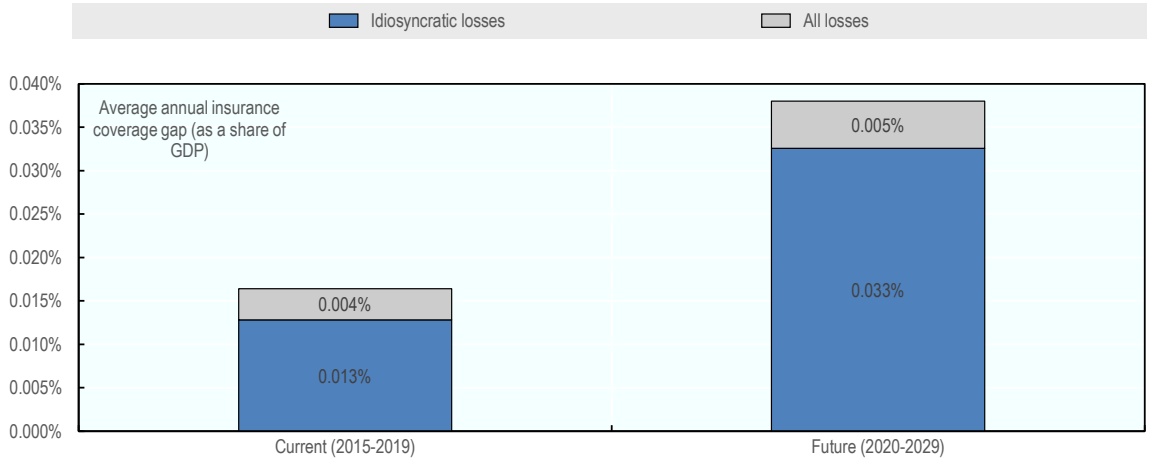
- For current (2015-2019) estimates, the economic loss estimates are based on the same estimates as above (cyber crime reports to IC3 (Internet Crime Complaint Center (IC3), 2020[203])), adjusted to account for non-crime cyber incidents (estimated to be account for 5% of all incidents based on NetDiligence claims data (NetDiligence, 2019[197])) and adjusted to provide global estimates (assuming the United States accounts for approximately 30% of cyber economic losses). Insured loss estimates are calculated for stand-alone cyber insurance policies, based on premium and loss ratios provided by Aon (Aon, 2020[220]) and adjusted to provide a global amount (assuming similar loss experience and that the US market accounted for a declining share of the total market between 2015 and 2019 – from 91% to 76%). Estimates of Equifax insured and uninsured losses were added to the loss distribution (idiosyncratic). Estimates of WannaCry and NotPetya insured and uninsured losses were added to the total (all losses). All loss data has been annualised and compared to the estimate of USD 6.7 billion in cyber insurance premiums.
- For future (2020-2029) estimates, economic losses were estimated based on a compound annual growth rate of 26.73% (the actual growth rate reported by IC3 from 2015-2019). The severity of a large data breach (similar to Equifax) is estimated to increase by 11% per year and the frequency

[112] For example, legal fees or forensic costs could increase if more resources are needed to provide confidence in attribution. In addition, not paying a ransom could lead to higher costs for data restoration and longer business interruption periods.

[113] Although the amount of coverage (and take-up of coverage) varies across countries, may property insurance policies will include some coverage for utility failures (potentially sub-limited and linked to physical damage or otherwise covered perils).

to increase from approximately 1-in-4 years to 1-in-3 years (based on data reported in (IBM, 2020[230])). The severity of a "systemic" ransomware attack is estimated to increase to USD 15 billion (based on a modelled scenario (Vohlers, 2020[231])). The frequency of a "systemic" ransomware attack is estimated to be 1-in-6 years based on the views provided by respondents to a survey including a question on the probability of a major cyber event (losses above USD 10 billion) (Willis Re, 2020[221])..

Figure A B.4. Average annual cyber risk insurance coverage gap

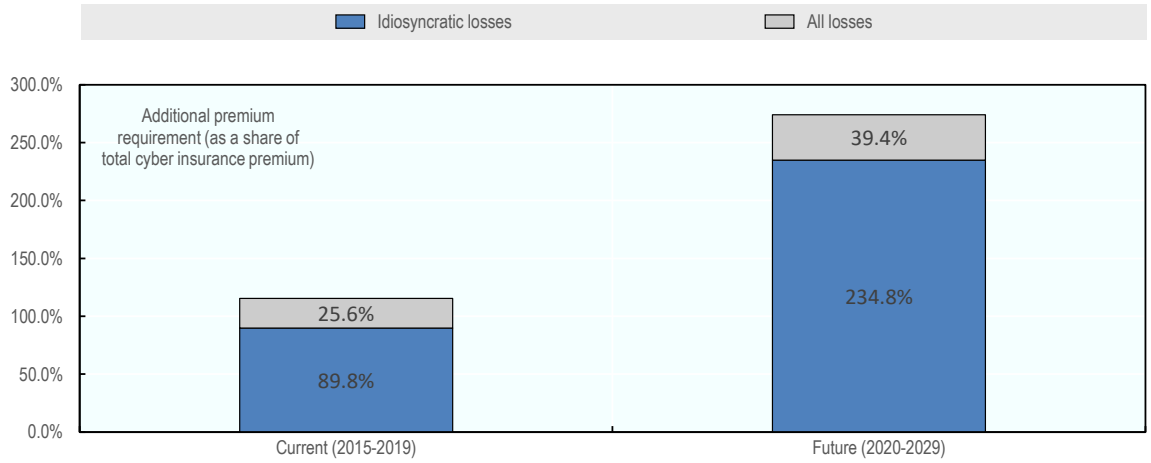


Source: OECD calculations (as outlined in the text above)

Figure B.5.present these estimates as the amount of additional premiums that would need to be collected by insurers across OECD countries (as a share of cyber insurance premiums – estimated to be approximately USD 6.7 billion) to provide a high-level of protection for cyber risk (60% of economic losses insured, slightly lower than the case of natural catastrophes given that cyber insurance policyholders are mostly businesses) for idiosyncratic and for all events (where the latter includes "systemic" ransomware attacks).

While based on much lower quality data than the natural catastrophe estimates above, the estimated cyber insurance gap in terms of additional premiums required to provide effective protection is much larger than in the case of natural catastrophes given the significantly lower premium base – although the actual magnitude of the gap in terms of uninsured losses is much smaller (approximately USD 18 billion on an annualised basis).

Figure A B.5. Estimated additional annual premium needed to address cyber insurance gaps



Source: OECD calculations (as outlined in the text above)

Annex C. Infectious diseases

Pandemic, epidemics and other infectious disease outbreaks have long been considered a potential catastrophe risk although with much of the focus dedicated to the potential losses in life, health and certain liability lines, such as workers' compensation/employer's liability. However, the experience of the COVID-19 health crisis – and particularly the measures taken by governments around the world to constrain the spread of the virus – has clearly demonstrated the potential for significant losses to be incurred for loss types that are normally covered in other lines of business (specifically, business interruption coverage in property insurance policies). The measures put in place to slow the spread of the virus in most countries led to a significant decline in business revenues as potential customers were unwilling or unable to make purchases and many businesses were forced to close altogether in order to be compliant with government requirements.

As discussed in a recent OECD report (OECD, 2021[232]) – and subject to ongoing disputes and litigation – many property and business interruption insurance policies do not appear to provide explicit coverage for business interruption losses in the context of a pandemic or other infectious disease outbreaks (with the exception of business interruption coverage for event cancellation in some policies). In many countries, business interruption coverage included in property insurance policies is only triggered upon the occurrence of physical damage. Many policies include coverage for business interruption losses that result from the closure of the insured business due to governmental order or loss of access to the place of business, although in many cases (but not all), this coverage is only triggered where the closure order is made as a result of physical damage to property in the vicinity of the insured property. Some policies also apply specific exclusions for damages or losses resulting from a virus which would also likely hinder policyholder recovery of losses even where there is no requirement for physical damage to trigger business interruption coverage (i.e. non-damage business interruption coverage).

A review of policy language undertaken by the Autorité de contrôle prudentiel et de résolution (ACPR) in France found that only 2.6% of reviewed insurers' policyholders had explicit business interruption coverage for a COVID-19-type event while a further 4.1% had coverage that could potentially respond (i.e. their policy wordings did not provide certainty on coverage) (ACPR, 2020[233]). In the United States, a data call by the National Association of Insurance Commissioners revealed that, as of November 2020, only 1.7% of submitted business interruption claims had been closed with a payment (and 12.8% remained open) (NAIC, 2020[234]) In the United Kingdom, a survey of hospitality-related businesses found that less than 1% of hospitality businesses, 3% of innkeepers and 4% of beer and pub businesses had received a positive response from their insurer regarding business interruption coverage for COVID-19 related closures (Gould, 2020[235]).

While subject to change based on the outcomes of ongoing claims disputes, estimates of total COVID-19 industry losses (across all lines) range from USD 50 – 70 billion (Evans, 2020[236]) of which approximately USD 10 billion – USD 20 billion may come through business interruption coverage (other than event cancellation).[114] Based on a one-month revenue loss estimate of USD 1.7 trillion for OECD countries (see

[114] The Geneva Association (Schanz, 2020[18]), based on figures from Willis Towers Watson, estimates total insured business interruption losses of approximately USD 20 billion to USD 40 billion, including event cancellation. Informal discussions with another market participant provided estimates of approximately USD 7 billion to USD 10 billion in business interruption losses worldwide (and USD 7 billion to USD 10 billion in event cancellation losses).

below), this would suggest a gap between economic and insured losses for pandemic-related business interruption losses related to the current COVID-19 crisis of at least 99%.

The applicability of coverage for business interruption in the context of widespread pandemic-related business closure orders has not been broadly tested prior to the COVID-19 health crisis. While few final judgements have been delivered, it is unlikely that the current disputes will result in a broad level of coverage for COVID-19 related business interruption coverage (i.e. many of the losses that business incurred are likely to be uninsured). In addition, it appears that many if not all insurers are applying (or strengthening) virus exclusions in property insurance policies upon policy renewal which means that – even if coverage is found for COVID-19 related losses – it is unlikely that broad coverage for these types of losses will be available for any future infectious disease outbreaks.

Potential drivers of underinsurance for infectious diseases

Form of coverage

As noted, for most types of businesses, business interruption coverage is provided as a component of property insurance coverage and only triggered as a result of physical damage to property (with the exception of policies that provide non-damage business interruption coverage). Many (but not all) of the disputes related to the COVID-19 health crisis are focused on whether contamination of an insured property by a virus (or properties in proximity to the insured property) constitutes physical damage that would trigger coverage for business interruption losses. Unless there is a broad finding that it does constitute physical damage – or a significant change in the conditions[115] applied to business interruption coverage in property insurance policies – it is unlikely that the property insurance coverage that most business acquire will be a source of coverage for these losses in the future. Without such a finding or change in approach – any future coverage for business interruption resulting from government responses to infectious disease outbreaks would likely need to be provided through a specific endorsement or a stand-alone policy which will have an impact on the level of take-up if coverage is voluntary.

Loss magnitude

The COVID-19 infectious disease outbreak is the only outbreak in recent years to have led to widespread business closure orders globally. The SARS outbreak in 2002-2004 and the MERS outbreak in 2015 led to travel restrictions, school closures and important economic impacts in some countries although businesses were never broadly required to close for extended periods of time.

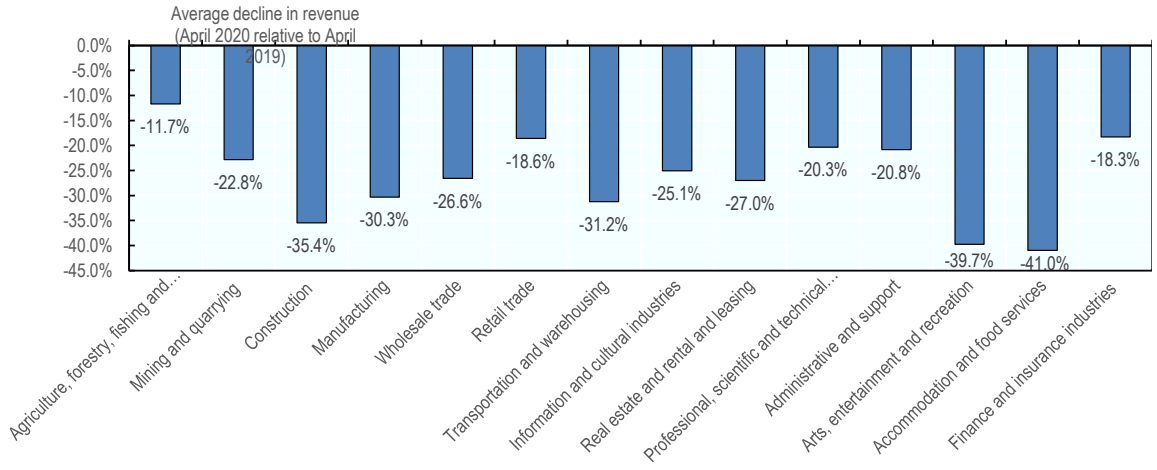
There have been a few estimates of the resulting economic losses. For example, the American Property Casualty Insurance Association estimated that "business continuity losses" (including incidental expenses, payroll obligations and lost profits) as a result of confinement measures for all businesses in the United States equalled approximately USD 1 trillion per month (Hartwig and Gordon, 2020[16]). The Geneva Association recently based its analysis of pandemic insurability on USD 4.5 trillion in global economic losses (Schanz, 2020[18]).

Other data sources may provide a more accurate assessment of actual losses in revenue faced by businesses, controlling for the differing impacts of confinement measures on different sectors. The initial set of confinement measures that occurred in March-June 2020 across most OECD countries had different impacts on businesses in different sectors. Some types of business activities were able to be maintained at (or near) normal levels. For example, one survey of US small businesses found that those businesses

[115] Eliminating the condition that business interruption coverage be triggered by physical damage would likely have a number of other consequences and lead to a broad expansion in the scope of losses covered by business interruption coverage in property insurance policies.

involved in service-type industries (such as retail or food services) and physical-type industries (such as construction or manufacturing) were much more likely to face severe decreases or even total losses of revenue than businesses operating in knowledge-type industries (SHRM, 2020[237]). In Canada, the national statistics office (Statistics Canada) undertook a survey of businesses to determine the change in businesses revenues in April 2020 (during the period of confinement) relative to April 2019. While the survey only provided ranges for revenue changes, there was sufficient granularity to allow for a rough calculation of the average decline in revenues across sectors (see Figure C.1).

Figure A C.1. Average decline in revenue by sector (April 2020 relative to April 2019, %): Canada

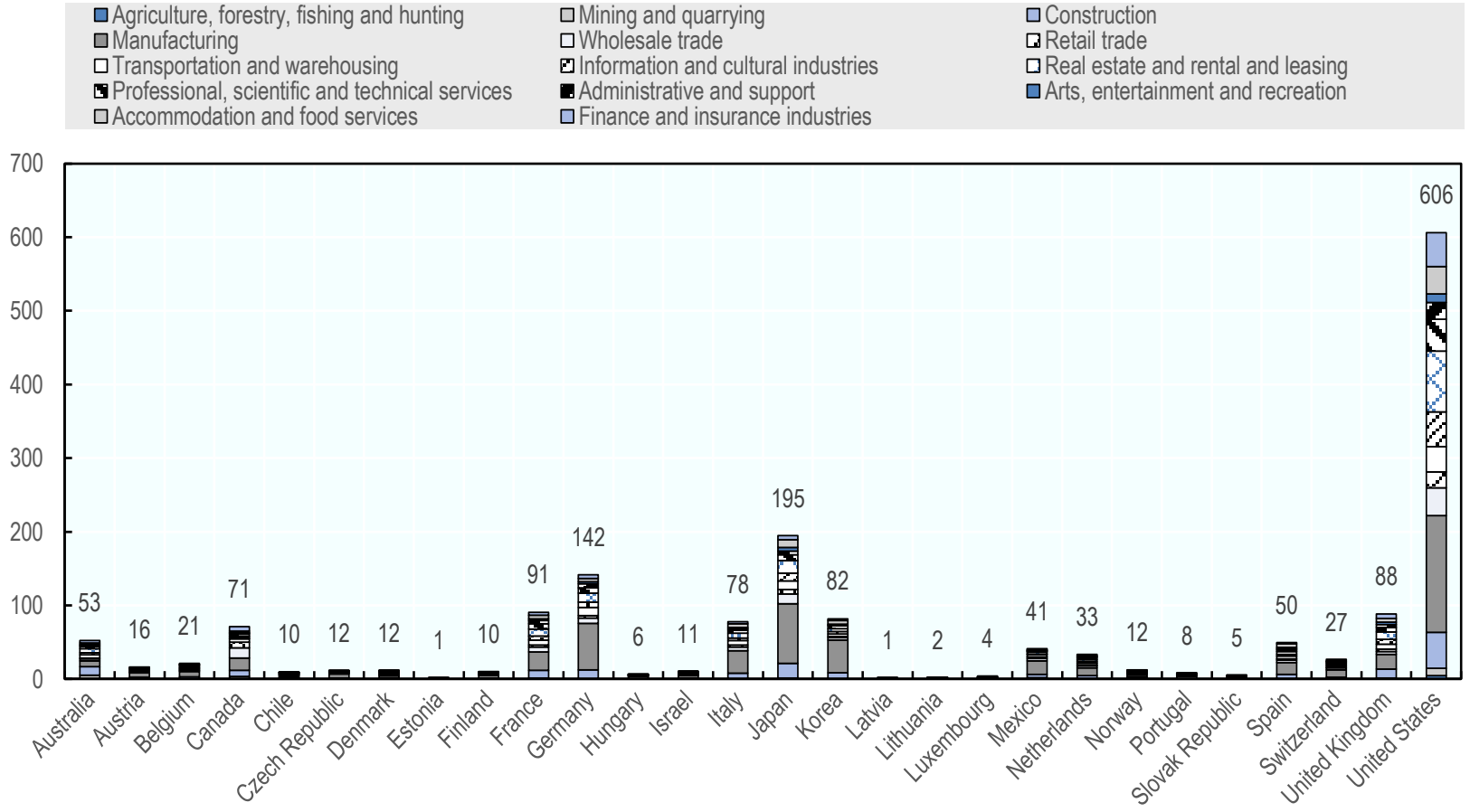


Source: OECD calculations based on (Statistics Canada, 2020[238]).

Figure C.2 applies these sector-level average declines in revenue across other OECD countries to provide estimates of the losses that would be incurred in different countries, adjusting for the different composition of business activities in different countries (and assuming that the different confinement measures resulted in similar impacts on revenues).[116] For the 27 OECD countries for which the necessary data was available (in addition to Canada, calculated based on (Statistics Canada, 2020[239])), a month of confinement measures could result in total business revenue losses of USD 1.7 trillion. The 28 countries included account for approximately 93% of OECD country GDP. Additional periods of confinement and business closures (as occurred and continue to occur in many countries) would of course increase the overall level of losses.

[116] Confinement measures were of course different across countries and also had different impacts on business revenues. In the United States, one estimate suggests that the overall decline in business revenues among small businesses reached 38.2% as of 30 April 2020 (relative to January 2020) (Chetty et al., 2020[272]) which is higher than the overall estimate for Canadian businesses (25.5%). In Australia, data on the share of businesses that faced decreases in revenue have been published (although not estimates of the amount of decline). In May 2020, it was estimated that 72% of businesses faced a reduction in revenues (Australian Bureau of Statistics, 2020[273]) which is comparable to the figure for the Canadian sample for April (70.2%).

Figure A C.2. Estimates of monthly impact of confinement measures on business revenues (USD billion)



Source: Data on output by business sector is taken from (OECD, 2020[240]). The latest available data for many countries was 2017 and so the figures were adjusted upwards to account for GDP growth in 2018 (from (OECD, 2020[4]) and inflated to 2019 USD.

It should be noted that, even if covered by insurance, it is unlikely that the total decline in revenues would be recoverable. Business interruption coverage claims payments are usually calculated based on changes in revenue net of changes in variable expenses such as input costs and may also adjust for changes in economic or market conditions. For example, a restaurant that is forced to close may not be able to recover revenues based on normal levels of business if other market conditions (such as a general decline in restaurant visits) would have likely led to a partial decline in revenues even if the restaurant had been able to remain open. A deductible (often a time-based deductible) is also usually applied. As a result of these factors, actual insured (or uninsured) business interruption losses due to COVID-19 will be lower than actual revenue declines.

Box A C.1. Increasing pandemic frequency?

While infectious disease outbreaks occur with high frequency around the world every year, large-scale and high severity epidemics and (particularly pandemics)[1] have been a rare occurrence. Since 1900, there have been only seven epidemics or pandemics[2] that have led to estimated deaths of over 1 million people (Encephalitis lethargica pandemic (1915), Spanish flu influenza pandemic (1918), Russia typhus epidemic (1918–1922), Asian flu influenza pandemic (1957–1958), Hong Kong flu influenza pandemic (1968-70), HIV/AIDS pandemic (1981-present) and COVID-19) – and only two (including COVID-19) in the last 50 years with airborne transmission (which might require business closures and other restrictions).

While scientific and medical advances may be expected to reduce the potential for infectious disease outbreaks or increase capacity to manage the outbreaks that do occur, other social and environmental trends may actually make future outbreaks more likely (The Vaccine Alliance (Gavi), 2020[241]), (Whiting, 2020[242]):

- Increased international travel facilitates the spread of diseases across countries as people can travel from one side of the world to the other in less time than the incubation periods of many diseases.
- Urbanisation – particularly in already over-crowded cities with underdeveloped sanitation services and health infrastructure – creates more environments that are conducive to the spread of infectious diseases to large numbers of people.
- Increased contact between humans and animals due to encroachment on natural habitats and the trade in wild animals create the conditions for inter-species spread of novel viruses for which there is no previous human immunity or known treatment options (approximately three quarters of known human diseases originated from other animals (WWF, 2020[243])).
- Higher temperatures as a result of a changing climate could increase the natural range of insects that spread diseases.

One study found that the number of infectious disease outbreaks has increased significantly over the past 30 years (along with the level of diversity in types of outbreaks) and now number approximately 200 epidemic events per year (World Economic Forum and Harvard Global Health Institute, 2019[244]).

[1] An epidemic refers to an increase, often sudden, in the number of cases of a particular disease in an area that is above the usual (or endemic) prevalence of the disease (CDC, 2012[245]). A pandemic refers to an epidemic that occurs worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people (Kelly, 2011[246]).

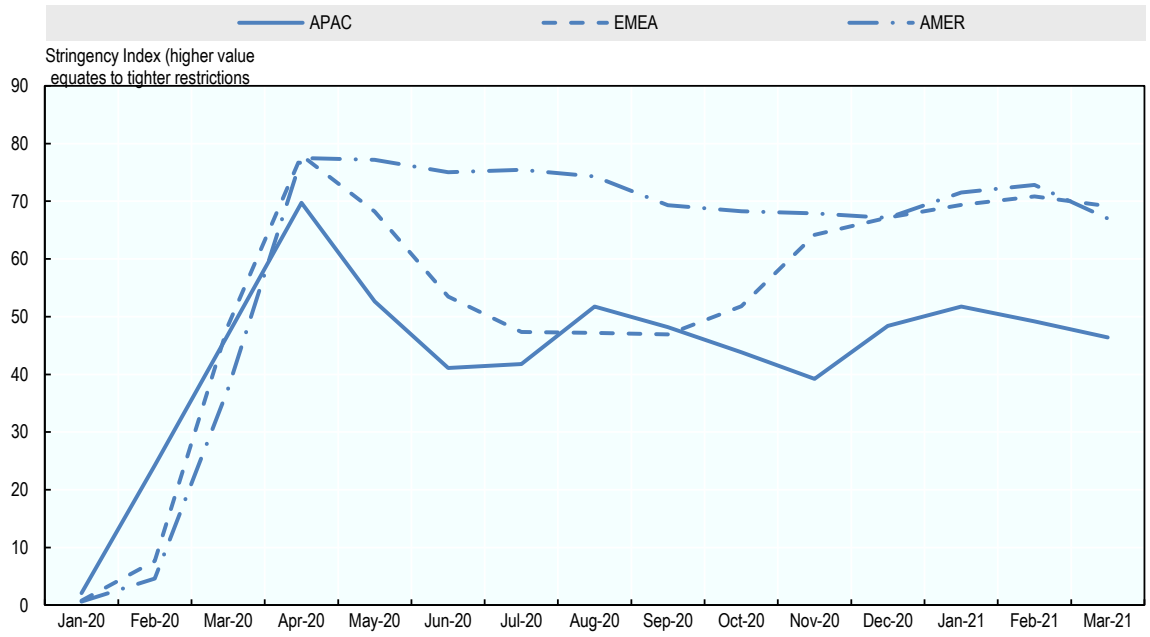
[2] There have been other severe epidemics and pandemics involving airborne transmission in recent years, including SARS (2002-2004), H1N1 swine flu (2009), Ebola (2013-2016 and 2018-2020), MERS (2015) as well as mosquito-borne viruses such as Zika and dengue fever although these outbreaks did not lead to widespread business closures.

Loss correlation

By definition, a global pandemic has near-simultaneous impacts across regions of the world so insurance (and reinsurance) companies providing coverage for pandemic-related losses would not be able to build a diversified pool of risks by assuming risks in different countries and regions. As noted, business interruption losses do not result directly from the spread of the virus but from measures taken by governments in response to the spread of the virus – which could (and did) vary in different countries. However, despite the differences in response, there was a still a very high level of correlation in terms of the measures taken by governments throughout 2020 and 2021. Figure C.3 provides a measure of severity of confinement

measures taken in different regions for each month in 2020 and the first quarter of 2021 (i.e. monthly average of daily severity for OECD countries in each region). The level of correlation across regions is very high (82% between Asia-Pacific and the Americas and 87% between Asia-Pacific and Europe and the Middle East and between Europe and the Middle East and the Americas). This suggests that losses from confinement measures put in place in response to a global pandemic that spread in a similar way as COVID-19 would be highly correlated and difficult to diversify.

Figure A C.3. Monthly index of severity of government measures across regions



Note: The stringency index records the strictness of confinement policies aimed primarily at restricting people's behaviour.
Source: OECD calculations based on (Blavatnik School of Government, 2020[247])

Based on the experience with COVID-19, a particular challenge with pandemics for insurers (and different from other catastrophe perils) is the correlation between claims impact (where covered) and financial market performance as financial markets lost significant value as governments began implementing measures to contain the spread of the virus. In addition to the (initial) loss in value for equity holdings driven by stock market declines and widening credit spreads, the impact of the closures on businesses is expected to lead to insolvencies and could ultimately result in losses in corporate bonds as well. As a result, in the context of a pandemic, insurers may face near-simultaneous losses on both sides of the balance sheet (assets and liabilities).[117]

The challenges related to global diversification in the context of a pandemic may not be present in the context of more localised or regionalised infectious disease outbreaks.

Uncertainty in risk assessment

Pandemic risk models for use in insurance have existed for a number of years (development began after the SARS outbreak in 2002-2004) and provide estimates of potential insured losses for the health and life

[117] In May, Lloyd's published an estimate for global insurance losses from COVID-19 which included USD 107 billion from claims payments and USD 96 billion from investment losses (Lloyd's, 2020[282]).

sector based on potential pandemic event footprints. The models apply epidemiological models of disease spread and impact for a large volume of potential outbreaks for a variety of different families of infectious diseases (influenza viruses, coronaviruses, etc.) and account for different types of potential pharmaceutical and non-pharmaceutical interventions (including lockdowns and travel restrictions). Some work was undertaken (pre-COVID-19) by the large catastrophe modelling firms to model potential pandemic-related business interruption losses although there was limited insurance sector demand for this type of analysis (likely because most insurers did not consider this type of loss to be a covered loss). There are also a small number of (re)insurance companies and specialised analytics firms that have developed models to quantify pandemic-related business interruption losses.[118]

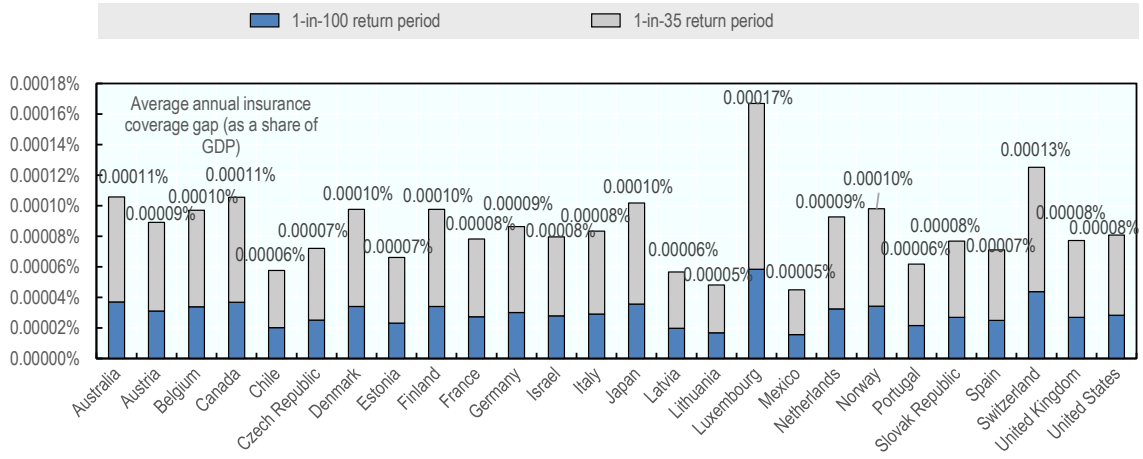
Modelling of pandemic risk involves a number of complexities including both epidemiological complexities related to the nature and evolution of viruses and the ability to develop treatments and vaccines as well as challenges in modelling the response behaviours of individuals and governments. In the case of business interruption, the trigger for losses to materialise (government closure orders) is particularly challenging to model as it requires an understanding of political decisions involving trade-offs between health and economy, perceptions of the level of pandemic preparedness (i.e. the ability to control the spread of the disease without broad closures) and the breadth and duration of lockdown measures necessary to get the virus under control (Schanz, 2020[18]). As a result of these factors, there is likely much more significant levels of uncertainty involved in assessing the risk of pandemic-related business interruption losses than for other types of catastrophe perils and losses.

Potential cost of limiting underinsurance for infectious diseases

Figure C.4 provides some estimates of the magnitude of the insurance coverage gap for infectious disease outbreaks as a share of OECD GDP. The estimates are provided for a 1-in-100 year return period (as the last global respiratory disease pandemic occurred approximately 100 years ago) and a 1-in-35 year return period based on the potential for increased frequency (and consistent with estimates published by The Geneva Association of a 1-in-30 to 1-in-40 year return period (Schanz, 2020[18])). The estimates are based on revenue decline estimates for one month of stringent confinement similar to the months of March/April in many countries – longer periods of stringent confinement would increase the amount of revenue declines and the additional premium required to provide coverage for those losses.

[118] For example, Munich Re has developed epidemic modelling in support of an insurance coverage for pandemic business interruption that was distributed prior to COVID-19. Metabiota is a specialised model provider that has also focused on this risk.

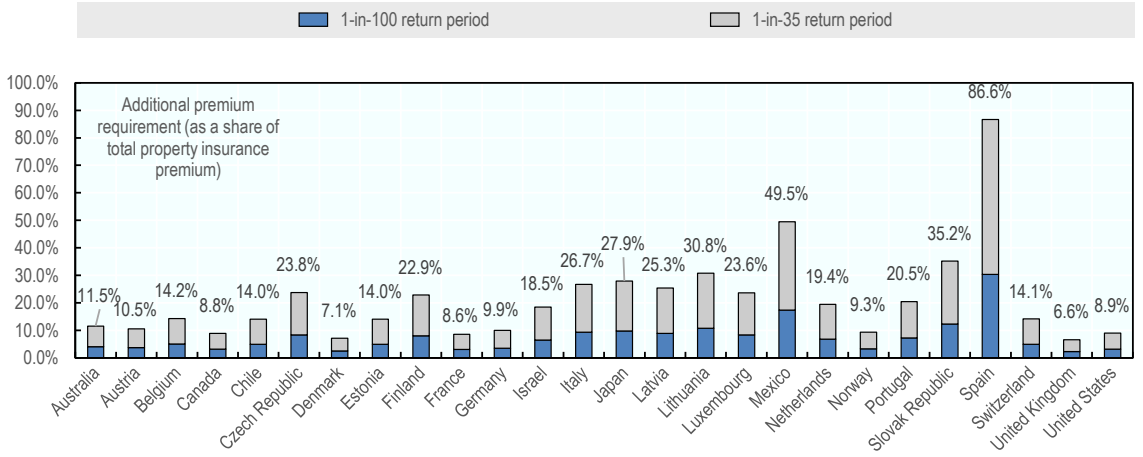
Figure A C.4. Average annual infectious disease outbreak insurance coverage gap



Note: Revenue decline estimates were derived as outlined in Figure C.2.
Source: OECD calculations as outlined in Figure C.2.

Figure C.5 provides some estimates of the amount of additional premiums that would need to be collected by insurers across OECD countries (as a share of property insurance premiums) to provide a high-level of protection for business interruption losses due to infectious diseases outbreaks (50% of estimated business revenue losses insured for one month, a lower level of coverage than the case of natural catastrophes and cyber risk given that policyholders are mostly businesses and that revenue figures presented are gross declines in revenue).

Figure A C.5. Estimated additional annual premium needed to address infectious disease insurance gaps



Note: Revenue decline estimates were derived as outlined in Figure C.2. The premium requirements were calculated to incorporate a loss ratio of approximately 65%.
Source: OECD calculations as outlined in Figure C.2. Property premium data is from (OECD, 2020[189]).

Annex D. Political violence, terrorism and social unrest

Political violence, terrorism and social unrest all have the potential to create significant property damage and business interruption losses:

- Political violence (from an insurance perspective) generally refers to war, civil war, rebellion and insurrection. It is normally excluded as a peril from property insurance policies although with the possibility of securing coverage through specialty lines (normally only acquired by large multinational corporations). In 2016, Lloyd's (where most relevant specialty lines are located) issued a market bulletin requiring all market syndicates to ensure that exclusions are applied for war risks (with the exception of a few classes of business) and that such risks could only be underwritten with Lloyd's express agreement (Lloyd's, 2016[248]) .
- Terrorism could be considered as a sub-component of political violence although it is often treated separately, partly as a result of the establishment of terrorism (re)insurance programmes in many countries to cover this risk. Coverage is normally excluded from property insurance (and other types of) policies except in countries where a terrorism (re)insurance programme exists. In those countries, coverage may be compulsory (e.g. France, Belgium for some lines of business and Australia based on the possibility to void exclusions for designated terrorist incidents) or it must be offered (e.g. United States) or it may be made available as a result of the coverage provided by the programme (e.g. United Kingdom). In the United States, approximately 62% of companies acquired insurance coverage for terrorism in 2018 as part of their property insurance coverage (Marsh, 2019[249]). Coverage for terrorism can also be secured through specialty lines (usually combined with other political violence perils).
- Coverage for damage and losses from social unrest (often referred to in insurance policies as strike, riot and civil commotion or SRCC) may be included in property insurance policies although some policies apply an exclusion for all or some SRCC perils (Dodge, 2020[250]), (Rosati and Kent, 2019[251]).

Based on available data from Swiss Re sigma (available for the years 1990-2016), there were 13 events classified as terrorist events in OECD countries (that met the minimum thresholds for a catastrophe event described in Box 1.2). Overall, the terrorist events resulted in USD 150 billion in economic losses (approximately USD 5.5 billion in average annual losses). The September 11th terrorist attacks in the United States accounted for just over 90% of the total economic losses from terrorist events. Approximately 22% of the economic losses from these terrorist events were insured. The share of losses insured for events that occurred since 2001 (and the establishment of most terrorism (re)insurance programmes) was also relatively low (approximately 15%) driven mostly by limited insurance coverage for losses from the 7 July bombings in London which targeted public transport. The data did not include the Lindt café attack on Sydney in December 2014 (insured losses of AUD 4 million (Willis Towers Watson, 2018[252]), the November 2015 terrorist attacks in the Paris region,[119] the March 2016 attacks in Brussels (EUR 113 million in insured losses (Willis Towers Watson, 2018[252])), the July 2016 attacks in Nice (France), the May

[119] PCS has provided estimates of approximately USD 20 million in insured losses.

2017 attack on a concert in Manchester (United Kingdom) (approximately USD 6 million in property damage (Pool Re, 2019[253])), the March 2019 attack on a mosque in Christchurch (New Zealand) or attacks in Istanbul and Ankara in 2016 (amongst many others)) so the level of economic losses from terrorism events is likely much higher. One estimate suggests that global economic losses from terrorism averaged approximately USD 83 billion per year between 2013 and 2017 (Marsh, 2019[249]).

As noted above (in the context of infectious diseases), business interruption coverage is often only triggered as a result of physical damage at (or in proximity to) the insured property. However, a terrorist attack could lead to losses in revenue that is not directly linked to physical damage at or near the insured premises, including losses resulting from restrictions on access to an area affected by a terrorist attack for investigative purposes (whether or not physical damage occurred – i.e. loss of access) as well as losses related to a decline in attractiveness to local or foreign consumers as a result of the attack (loss of attraction). For example, the June 2017 terrorist attack at the Borough Market in London resulted in lost revenues for market vendors during a one-week closure of the market following the attack. However, UK terrorism (re)insurance programme (Pool Re) was unable to provide any coverage for these losses as no property damage had occurred as a result of the attack (Khan and Skerratt-Williams, 2018[254]). The 2015 terrorist attack in the Paris region led to an estimated EUR 2 billion in lost revenue and extra expense for local businesses as a result of a decline in tourist visits (Schmude, Karl and Weber, 2020[255]).

There were 11 events classified as social unrest that met the catastrophe thresholds. These events led to USD 5.2 billion in total economic losses (approximately USD 200 million annually). Approximately 46% of these losses were insured (for events that included estimates of both insured and economic losses). Levels of insured losses were lowest for social unrest catastrophes in Athens in 2008 and the Paris region in 2005. The data does not include significant social unrest in Chile in 2019-2020 (estimated to be just below USD 3 billion in insured losses) and the unrest in the United States in 2020 which one estimate suggests has resulted in insured losses of more than USD 2 billion.[120]

As noted, war is (almost) universally excluded from insurance coverage and therefore any losses resulting from a war event would be uninsured.

Potential drivers of underinsurance for political violence, terrorism and social unrest

Form of coverage

Insurance coverage for damages and losses from strikes, riots and civil commotion varies across policies and may be excluded or only provided as an endorsement.

Insurance coverage for damages and losses from terrorist attacks is usually only broadly provided where there is a terrorism (re)insurance programme in place (in countries without such a programme, businesses normally need to seek coverage from specialty markets for this peril). As a result, a terrorist attack in a country that does not have a terrorism (re)insurance programme would likely result in losses that are largely uninsured.

Similar to natural catastrophes, where coverage for terrorism is an optional endorsement to property insurance policies (i.e. where the coverage provided by terrorism (re)insurance programmes is an optional addition to coverage), the share of losses covered by insurance will generally be lower than where such coverage is mandatory. While there have been few events with available data on insured and economic losses, the two terrorist attacks in Spain (where coverage is automatically included in property insurance

[120] Estimates provided informally by PCS.

coverage) resulted in a higher share of losses insured than the events in the United Kingdom and Belgium (where coverage is optional (at least for some lines, in the case of Belgium)).

Terrorism (re)insurance programmes that provide coverage as reinsurance will only incur claims if there is coverage in the underlying (reinsured) policy. As a result, unless the scope of coverage is mandated, some primary polices may not provide coverage for losses for which coverage is available through the terrorism reinsurance programme. For example, losses from a cyber-terrorism attack for which terrorism (re)insurance programme coverage may be available (see above discussion on cyber insurance) will only be covered by the programme if the underlying policy did not apply an exclusion for cyber-related losses. Similarly, terrorism reinsurance programmes that provide some coverage for non-damage business interruption would only make payouts on that coverage if the policyholder's primary insurer included coverage for this type of loss. A number of terrorism (re)insurance programmes have taken steps to address potential gaps in coverage for cyber-terrorism and loss of access (e.g Pool Re in the United Kingdom) although these efforts to provide additional protection will only be effective if primary insurers also extend this coverage to policyholders.

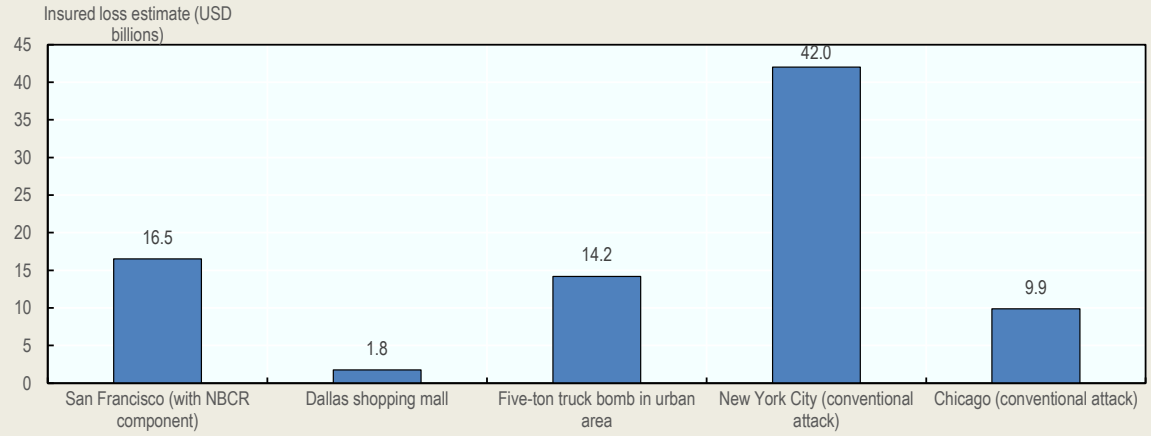
Loss magnitude

Most of the terrorist attacks and social unrest, particularly since the September 11th terrorist attacks in the United States, have resulted in much lower levels of physical damage than natural catastrophe perils. Since that time, there has only been one episode of social unrest (Greece, 2008) and one terrorist attack (London bombings in 2005) that have led to physical damage and consequential business interruption losses of over USD 1 billion. That said, a major terrorist attack in a densely populated urban area could result in massive damages (and mass casualties) similar in magnitude to large natural catastrophe events (Box D.1).

Box A D.1. US Federal Insurance Office terrorist attack scenarios

The US Treasury's Federal Insurance Office has published three bi-annual reports on the effectiveness of the Terrorism Risk Insurance Program that include the results of a data request to insurers to estimate modelled (insured) losses that could result from different types of major terrorist attacks on a US city. These estimates provide an illustration of the potential damages that could result from a major terrorist attack (see Figure D.1).

Figure A D.1. Insured loss estimates: FIO terrorist attack scenarios



Note: The figures for New York City and Chicago are rough estimates based on the published charts as actual estimates were not published.
Source: (FIO, 2020[69]), (FIO, 2018[256]), (FIO, 2016[257])

Loss correlation

Social and political events are likely to have an impact on the level of motivation of terrorist organisations to undertake an attack which could lead to some correlation in the timing of events across different countries. However, given the challenges in mounting a successful terrorist attack, it is unlikely that there will be a high-level of correlation in the timing of major successful events even if there are surges in motivation. The available data does not allow for an examination of the level of correlation across past attacks.

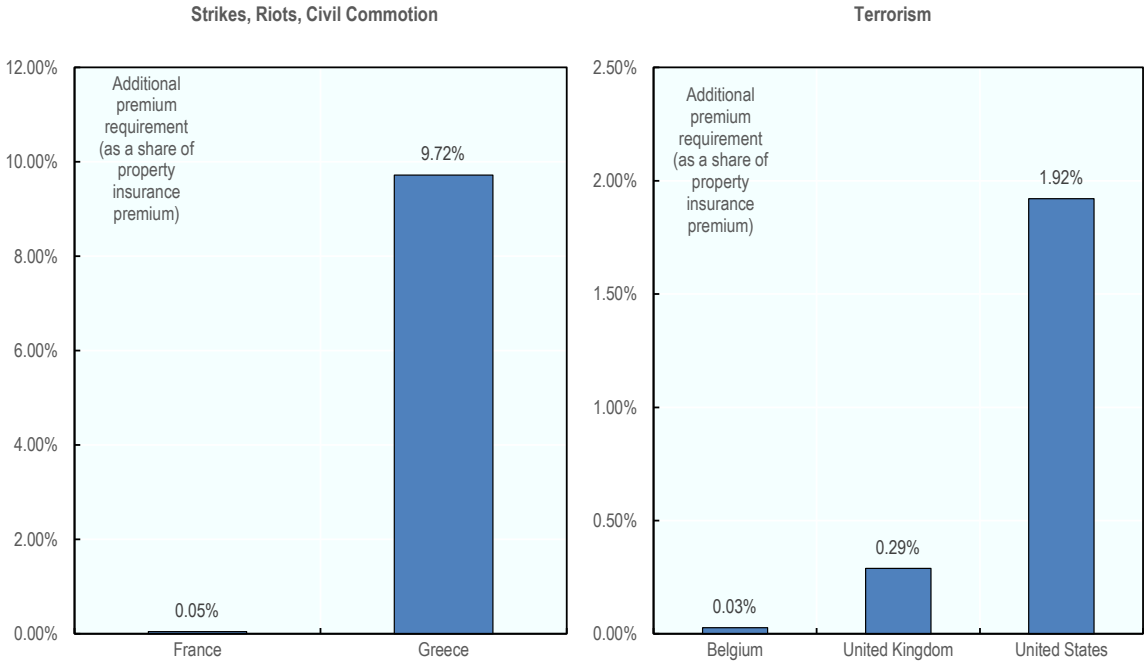
Uncertainty in risk assessment

Similar to cyber risk, assessment of terrorism risk involves an assessment of human behaviour including the motivation and capacity of terrorist organisations to mount a terrorist attack and the effectiveness of counter-terrorism authorities in thwarting an attack. Terrorism models have been available for a number of years, partly driven by the efforts of terrorism (re)insurance programmes in various countries to improve the availability of risk analytics. In the place of scientific expertise in disciplines such and meteorology and geology, terrorism risk modellers incorporate expert judgement to assess potential frequency and severity of terrorist attacks (Chia, 2016[258]).

Potential cost of limiting underinsurance for political violence, terrorism and social unrest

Figure D.2 provides some estimates of the amount of additional premiums that would need to be collected by insurers across selected OECD countries (as a share of property insurance premiums) to provide a high-level of protection for terrorism and social unrest risk (60% of economic losses, the same as for cyber risk as property damage losses have generally affected businesses) – based on the very limited data available for these perils (i.e. two social unrest events and ten terrorist attacks). Based on recent experience – and the very limited available data – the gap in insurance for these perils appears to be much less significant than for other perils although this is clearly driven by a lack of events that resulted in significant property damage since September 11th. However, as noted above, many of the costs of political violence and social unrest may be indirect and not included in estimates of economic losses.

Figure A D.2. Estimated additional annual premium needed to address terrorism and social unrest insurance gaps



Source: OECD calculations based on (OECD, 2020[189]) and data provided by Swiss Re sigma.

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