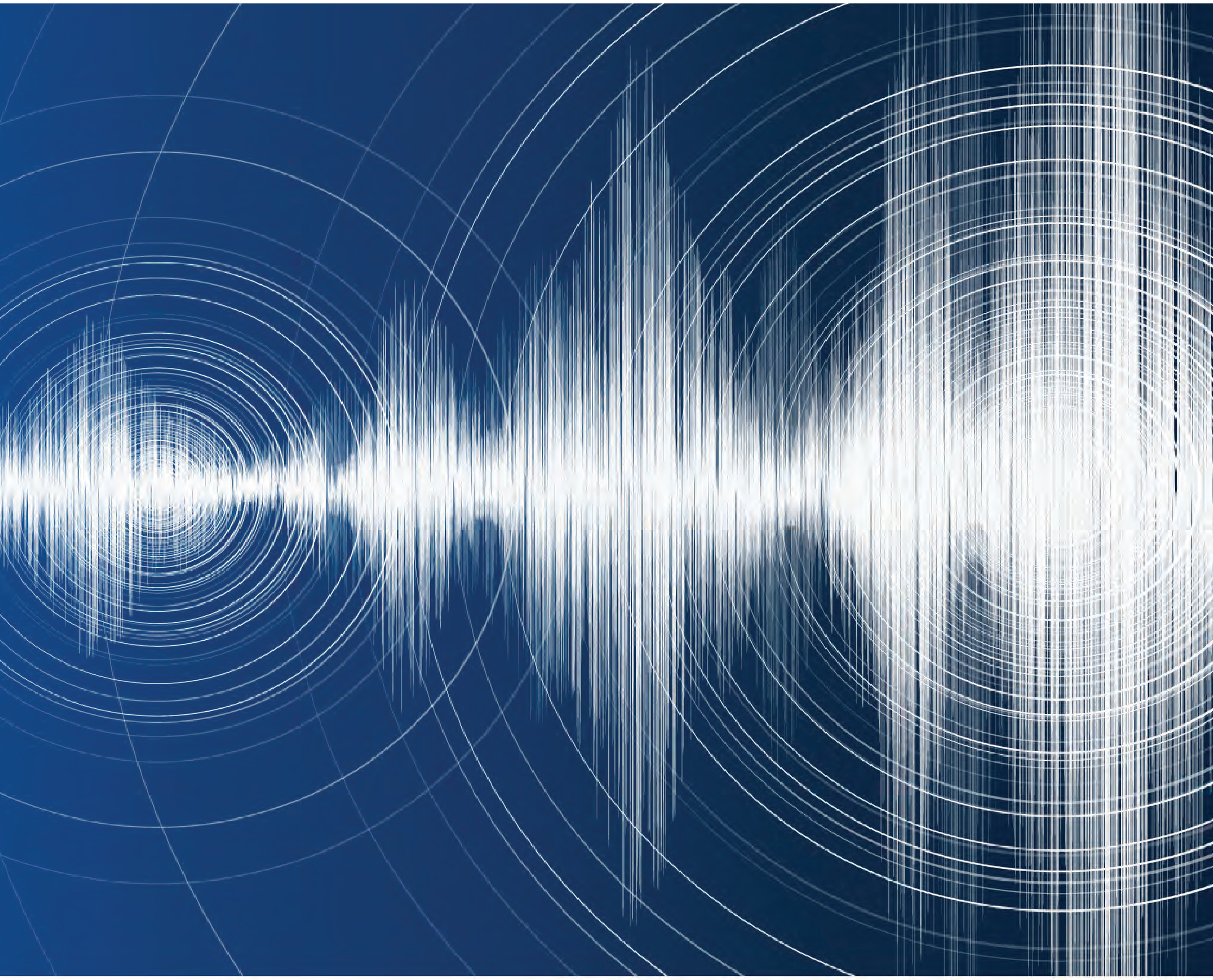
Financial Management of Earthquake Risk



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Please cite this publication as:

OECD (2018), *Financial Management of Earthquake Risk,* *www.oecd.org/finance/Financial-Management-of-Earthquake-Risk.htm*.

Foreword

Disasters present a broad range of human, social, financial, economic and environmental impacts, with potentially long-lasting, multi-generational effects. The financial management of these impacts is a key challenge for individuals, businesses and governments in developed and developing countries.

The *Financial Management of Earthquake Risk* applies the lessons from the OECD's analysis of disaster risk financing practices and the application of its guidance to the specific case of earthquakes. The report provides an overview of the approaches that economies facing various levels of earthquake risk and economic development have taken to managing the financial impacts of earthquakes.

The OECD supports the development of strategies and the implementation of effective approaches for the financial management of natural and man-made disaster risks under the guidance of the OECD High-Level Advisory Board on Financial Management of Catastrophic Risks and the OECD Insurance and Private Pensions Committee. This work includes the *OECD Recommendation on Disaster Risk Financing Strategies* (OECD, 2017) which 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. This work has been welcomed by international fora, such as G20 Finance Ministers and Central Bank Governors and APEC Finance Ministers, who have reocgnised the importance of building financial resilience against these risks.

This report was prepared by Fatih Alpaslan Yilmaz, a secondee from Turkey to the OECD, with contributions from other members of the OECD Division for Financial Affairs. It is based on responses from 31 countries to a survey questionnaire, as well as research undertaken by the OECD Secretariat. The report benefited from the support and input of the OECD High-Level Advisory Board on the Financial Management of Catastrophic Risks and the OECD Insurance and Private Pensions Committee.

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Abbreviations and acronyms

CCR	*Caisse central de reassurance* (public reinsurer in France)
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CCS	Consorcio de Compensación de Seguros (public insurer in Spain)
CEA	California Earthquake Authority (United States)
CRED	Centre for Research on the Epidemiology of Disasters
EM-DAT	Centre for Research on the Epidemiology of Disasters' Emergency Events Database
EQC	Earthquake Commission (New Zealand)
FEMA	Federal Emergency Management Agency (United States)
GDP	Gross Domestic Product
ICI	Iceland Catastrophe Insurance
IMF	International Monetary Fund
INS	*Instituto Nacional de Seguros* (public insurer in Costa Rica)
JICA	Japan International Cooperation Agency
JER	Japan Earthquake Reinsurance
NPP	Norwegian Natural Perils Pool
OECD	Organisation for Economic Co-operation and Development
PAID	Insurance Pool Against Natural Disasters (Romania)
PDRFI	Pacific Disaster Risk Financing and Insurance
TCIP	Turkish Catastrophe Insurance Pool
TREIF	Taiwan Residential Earthquake Insurance Fund (Chinese Taipei)
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations Office for Disaster Risk Reduction
USGS	United States Geological Survey
WB	The World Bank Group

Executive summary

Earthquakes are one of the most destructive natural perils and can lead to severe economic, social and environmental impacts. Since 1990, more than 800 000 people have lost their lives as a consequence of earthquakes, which have caused an average of USD 34.5 billion in damages annually. Rapid urbanisation, the accumulation of assets in seismic areas – and, to some extent, increasing induced seismicity – have led to an increasing amount of exposure to earthquake risk in many parts of the world.

Insurance can make an important contribution to managing the financial impacts of earthquake risk, although the insurability of earthquake losses faces a number of challenges. As a result, public earthquake (re)insurance arrangements have been established in some countries to support broader insurance coverage, in particular among households. Other countries have taken other measures to improve earthquake insurance take-up, although a high-level of underinsurance of earthquake risk in most parts of the world remains, including as a result of significant levels of co-insurance. This financial protection gap for earthquake risk leaves households and businesses – and ultimately governments – vulnerable to losses stemming from earthquakes.

Enhancing public awareness about earthquake risk and facilitating the purchase of financial protection generally leads to higher insurance coverage for earthquake risk, although the infrequency of major earthquakes and the high cost of insurance in high-risk zones have often made it difficult to encourage sufficient demand for insurance. Investing in risk reduction through improved land use planning and building codes and by retrofitting vulnerable structures (including non-structural components) can reduce the potential for damage from future earthquake events and improve insurability. In the case of earthquake risk, it is particularly important to leverage opportunities to "build back better" in the aftermath of destructive events. Improving the quality and availability of seismic maps and earthquake models and investing in enhancing the scientific knowledge of earthquake processes, including the continued identification of potentially active fault lines, can provide valuable input for better understanding and managing earthquake exposure and support insurability.

Earthquakes also create contingent liabilities for governments which face costs for emergency response and recovery, repair of public assets and any financial assistance or compensation provided to those affected. These costs can have a material impact on public finances and therefore need to be carefully managed. The way costs are managed can also impact incentives for risk reduction faced by households, businesses and sub-national levels of government so different approaches to managing public financial exposures requires careful consideration.

Surveyed countries

The report benefited from responses to a questionnaire from 31 economies, both OECD member and non-member economies: Afghanistan, Albania, Austria, Canada, Chile, Chinese Taipei, Colombia, Costa Rica, Finland, France, Germany, Hungary, Iceland, Japan, Laos, Latvia, Luxemburg, Macedonia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Portugal, Russia, Serbia, Spain, Sri Lanka, Switzerland, Turkey and United States. The responding economies face very different levels of earthquake risk and insurance market development which has led to very different approaches to the financial management of earthquake risk.

Key findings

- **The ability to quantify exposure to earthquake risk is a prerequisite to the effective financial management of earthquake risk and a necessary input for assessing costs and benefits of different approaches to risk reduction and transferring risk to (re)insurance capital markets.** Development of maps and models of seismic risk, including secondary loss agents, should be encouraged to improve assessment of potential exposures. Government investment in improving the availability of data on structures and soil conditions, historical events and the understanding of underlying physical seismic processes can make an important contribution to improving the accuracy of maps and models and therefore the assessment of exposure that is derived. Support for seismological research is also critical for identifying active fault lines and their potential to trigger powerful events.
- **The existing insurance arrangements for earthquake risk in most countries are not providing comprehensive coverage for losses and damages.** Losses and damages from earthquakes are particularly difficult to manage. Insurance and reinsurance arrangements supported or backed by government have contributed to achieving higher levels of earthquake insurance protection, especially in countries facing high levels of earthquake risk. Whether provided by public or private insurers, facilitating earthquake insurance purchase by households and businesses, including by requiring that policyholders specifically opt-out of including earthquake coverage in their property policies, incorporating earthquake coverage into standard policies by default and/or bundling of earthquake risk with other perils, can contribute to achieving higher levels of coverage given the low level of take-up of earthquake insurance in many countries. The contribution of insurance to the financial management of earthquake risk will be maximised where insurance promotes cost-effective risk reduction measures and comprehensive enforcement of building codes. Risk-based premiums, including premium discounts for risk reduction measures, can encourage risk reduction. The regulatory framework should be designed to support the contribution of insurance to financial management of earthquake risk, including by allowing for the accumulation of reserves and access to international reinsurance and capital markets, particularly where risks are high.
- **Government involvement is key in supporting the insurability of earthquake risk.** Governments can help address some of the challenges to the insurability of earthquake risk by investing in measures to improve risk awareness and reduce the overall level of risk. Efforts to incentivise new seismic-resistant building technologies, support strong building codes, identify the structures that are most vulnerable to earthquakes and secondary perils and encourage risk reduction investments can make an important contribution to reducing the level of exposure. Particular opportunities to reduce the level of risk are likely to emerge in the

aftermath of a destructive event. International organisations should support this objective in their country programmes.

- **Effective coordination across government is critical for establishing an integrated approach to the financial management of earthquake risk that considers the best-use of limited public resources and takes into account the costs and benefits of different approaches (including the incentives created by different interventions).** Given the range of policy tools that need to be considered, a holistic approach to the financial management of earthquake risk requires effective coordination across government, including across levels of government, supported by strong leadership aimed at addressing the financial vulnerabilities created by exposure to earthquake risk. Earthquake-related contingent liabilities for public finances can be minimised by carefully evaluating the cost-effectiveness of different approaches to managing risk, reducing the scope of financial assistance and public (re)insurance arrangements and by maximising the share of risk transferred to the private sector.

Chapter 1.

Designing a disaster risk financing strategy for earthquake risk

This chapter outlines the main findings from the report and lessons for applying these findings in the development of a disaster risk financing strategy.

The effective financial management of earthquake risk is a complex public policy challenge, particularly for countries faced with significant exposures and/or limited capacity to manage potential financial impacts. Managing financial impacts of earthquakes requires a holistic approach based on a careful assessment of exposure and options that consider the full range of possible policy approaches for managing the exposure.

The *OECD Recommendation on Disaster Risk Financing Strategies* (2017) provides some principles for - and outlines the main components of - an effective strategy for managing the financial impacts of disasters, including:

- promoting comprehensive risk assessment processes that allow for estimation of exposures and identification of financial vulnerabilities;
- supporting effective management of the financial impacts of disasters by all segments of the population and economy and encouraging the development of risk transfer markets for disaster risks; and
- managing the financial impacts of disasters on public finances.

The following sections outline how these can be applied in developing a strategy for the financial management of earthquake risk, based on the findings of this report.

Assessing exposure to earthquake risk

A comprehensive assessment of earthquake risk, including financial vulnerabilities that a major earthquake could create, is a prerequisite for the design of a strategy to manage the financial impacts of earthquake risk. It is necessary for informing decisions on emergency response, land use planning, building codes and risk reduction investments, as well as for developing options for managing earthquake-related contingent liabilities in public finances. It is also a prerequisite for underwriting and transferring earthquake risk to insurance and capital markets.

In the case of earthquake risk, there are a number of challenges to developing accurate assessments. Damaging earthquakes are relatively infrequent, which means there is a more limited set of events from which to gather data and incomplete knowledge about the existence and seismic potential of all active faults. Geological factors that lead to earthquakes are complex and not completely understood while the potential for secondary loss agents, such as fire, tsunamis, liquefaction and aftershocks, make modelling potential damage from earthquakes extremely complex. In addition, new exposures to earthquake risk are being created as a result of human activities that are putting more stress on fault lines and leading to earthquakes in areas that were not previously susceptible to such events.

The scope and coverage of seismic risk maps and models has improved, often driven by demand from stakeholders - including insurance companies and their regulators - for more sophisticated assessments of earthquake risk. The number of countries covered by models is increasing, although the modelling of secondary perils remains limited outside of a handful of larger markets. Ultimately, the accuracy of models depends on improving (and integrating) scientific knowledge, the availability of quality data, including event data and building inventory data that is often (but not only) collected by governments, as well as improvements in the scientific understanding of earthquake causation. Government investment in these areas can contribute to enhancing the capacity of models to provide accurate assessments of earthquake risk.

Supporting the effective management of the financial impacts of disasters

A disaster risk financing strategy should aim to ensure that the financial impacts of a disaster event can be managed without creating significant financial vulnerabilities or economic disruption, while providing appropriate incentives for risk reduction. Encouraging broad insurance coverage can contribute to this objective as countries with higher levels of insurance penetration tend to face more limited economic disruption. insurance normally provides a timely source of financing for reconstruction and reduces potential costs to the public sector in covering uninsured losses.

However, as outlined in Chapter 4, there are a number of challenges to the insurability of earthquake risk, including uncertainty about exposure and the potential for significant losses that lead to insurance premiums that are higher than many households and businesses are willing to pay. This has led to significant underinsurance of earthquake risk in most parts of the world and, therefore, significant contingent liabilities for governments that are expected to assist those without sufficient insurance in the aftermath of a major earthquake.

To address this financial protection gap, earthquake insurance coverage in many countries is offered directly (or backed) by a public (re)insurance scheme. In countries that are highly-exposed to earthquake risk, these schemes have often been established in the aftermath of a significant earthquake as a result of limited private insurance sector capacity or appetite for offering earthquake insurance. These interventions have normally led to an increase in the level of earthquake insurance penetration although, in many cases, significant underinsurance remains either as a result of low penetration or high-levels of co-insurance. In other countries, including some countries that face high-levels of earthquake exposure, the private sector is the main provider of earthquake insurance coverage. In most of these countries, earthquake insurance penetration is low, although there are some countries that have achieved penetration rates similar to those countries with dedicated public insurance schemes.

Whether provided by the public or private sector, facilitating the purchase of insurance by households and businesses can have important benefits in terms of increasing penetration. Penetration rates for earthquake coverage are almost always higher in countries where the default option is to include that coverage in standard residential and commercial property policies. Penetration rates are also higher where banks require that buildings whose purchase they have financed are covered by earthquake insurance (although only where a significant share of property owners has a mortgage). Higher levels of penetration will lead to a larger pool of diversified risks which should contribute to overall insurance affordability. The bundling of earthquake coverage with other natural perils can also have a positive impact on diversification (and affordability) and could potentially support higher demand as some households may purchase the bundled coverage due to concerns about their exposure to other natural perils.

Where there are significant challenges to the insurability of earthquake risk, there are a number of measures that governments can take to address some of those challenges. Investments in improving public understanding of earthquake risk and the need for financial protection, taking into account lessons on effective approaches to risk communication, can contribute to increasing willingness-to-pay for earthquake insurance. Effective communication is particularly important when earthquake coverage is not included as the default option for residential and commercial policyholders. There is some evidence that forms of risk communication that focus on return probabilities within shorter time periods, build on recent earthquake experience and provide estimates of the potential level of earthquake damage may be more effective in encouraging households and businesses to seek financial protection. Minimising misunderstandings about the scope of earthquake coverage, as well as clarifying the extent of possible public disaster assistance, may also be beneficial in increasing the demand for earthquake coverage.

Ex ante risk reduction investments, such as restrictions on building (or vulnerable building types) in high seismic areas, improving and enforcing construction standards for new buildings and reducing the vulnerability of existing buildings (seismic retrofitting) can reduce earthquake-related losses and support insurability. In built-up areas, this will likely require a longer-term seismic mitigation strategy that includes plans to replace vulnerable buildings with new ones when retrofitting is not feasible or no longer cost effective. In these areas, governments should also maximise opportunities to reduce risk in the aftermath of destructive events. Voluntary implementation of risk reduction measures by individuals is limited due to many of the same factors that result in low take-up of insurance (low awareness, affordability concerns and expectation of government financial assistance) and can be encouraged by providing credible guidelines on affordable and cost-effective mitigation measures. Incentives such as tax exemptions and the availability of long-term loans can encourage households and businesses to implement risk reduction measures. Insurance premiums and deductibles that reflect risk - and provide discounts for risk mitigation - can also provide incentives for risk reduction.

The regulatory framework for the management of earthquake losses by insurance companies, including requirements related to the establishment of earthquake reserves and the use of reinsurance and capital markets risk transfer, will impact the capacity of the insurance sector to provide earthquake insurance coverage. For example, measures that restrict the use of cross-border reinsurance risk transfer, while potentially allowing for closer supervision of counterparty risk, could lead to higher reinsurance prices for primary insurers and increase the cost of earthquake insurance for households and businesses.

Managing the financial impacts of disasters on public finance

The public sector is exposed to earthquake risk through the costs of relief and recovery, reconstruction of public assets, payments as compensation and financial assistance to individuals, business and/or sub-national levels of government, as well as any costs related to public (re)insurance schemes that provide coverage for earthquake damages and losses. There are a variety of ways to manage these public sector contingent liabilities, including through efforts to minimise the cost of financial assistance and/or public (re)insurance schemes and by securing financial protection for some part of the overall damage and loss. The establishment of public (re)insurance schemes that provide broad coverage for earthquake risk is one means of reducing the likely scope of *ex post* compensation and financial assistance, especially in countries where private insurance markets are not able to achieve broad levels of coverage. Careful management of the scope of public insurance arrangements by maximising the contribution of private markets can make an important contribution to minimising the overall cost of such arrangements.

The most significant costs often relate to the rebuilding of public infrastructure, often financed through cost-sharing arrangements between national and sub-national governments (that are often responsible for a large share of public infrastructure assets). Financial assistance to sub-national governments, taking into account the relative fiscal capacity of each level of government, can be critical for supporting the ability of sub-national governments to manage the financial impacts of earthquakes. However, national governments need to ensure that such assistance does not discourage investment in risk reduction or financial protection at the sub-national level.

Box 1.1. Key policy messages for the design of a disaster risk financing strategy for earthquake risk

The ability to quantify exposure to earthquake risk is a prerequisite to the effective financial management of earthquake risk and a necessary input for assessing the costs and benefits of different approaches to risk reduction and transferring risk to (re)insurance capital markets.

- The development of maps and models of seismic risk, including secondary loss agents, should be encouraged to improve the assessment of potential exposures.
- Government investment in improving data availability on structures and events and the understanding of underlying physical geological processes can make an important contribution to improving the accuracy of maps and models and therefore the assessment of exposure that is derived.

Existing insurance arrangements for earthquake risk in most countries are not providing comprehensive coverage for losses and damages.

- Losses and damages from earthquakes are particularly difficult to manage. Insurance and reinsurance arrangements supported, or backed by, government have contributed to achieving higher levels of earthquake insurance protection, especially in countries facing high levels of earthquake risk.
- Whether provided by public or private insurers, facilitating earthquake insurance purchase by households and businesses, including by requiring that policyholders specifically opt-out of including earthquake coverage in their property policies, incorporating earthquake coverage into standard policies by default and bundling of earthquake risk with other perils, can contribute to achieving higher levels of coverage.
- The regulatory framework should be designed to support the contribution of insurance to the financial management of earthquake risk, including by allowing for the accumulation of reserves and access to international reinsurance and capital markets, particularly where risks are high.
- The contribution of insurance to the financial management of earthquake risk will be maximised where insurance promotes risk reduction. Risk-based premiums and premium discounts for risk reduction measures can encourage risk reduction.

Government involvement is key in supporting the insurability of earthquake risk.

- Governments can help address some of the challenges to the insurability of earthquake risk by investing in measures to improve risk awareness and to reduce the overall level of risk. Efforts to identify the structures that are most vulnerable to earthquakes and secondary perils and encourage risk reduction investments can make an important contribution to reducing the level of exposure. Particular opportunities to reduce the level of risk are likely to emerge in the aftermath of a destructive event.

- International organisations should support this objective in their country programmes.

Effective coordination across government is critical for establishing an integrated approach to the financial management of earthquake risk that considers the best-use of limited public resources and takes into account the costs and benefits of different approaches (including the incentives created by different interventions).

- Given the range of policy tools that need to be considered, a holistic approach to the financial management of earthquake risk requires effective coordination across government, including across levels of government, supported by strong leadership aimed at addressing the financial vulnerabilities created by exposure to earthquake risk.
- Earthquake-related contingent liabilities for public finances can be minimised by carefully evaluating the cost-effectiveness of different approaches to managing risk, reducing the scope of financial assistance and public (re)insurance arrangements and by maximising the share of risk transferred to the private sector.

Few countries broadly use risk transfer arrangements to manage their earthquake-related contingent liabilities (although innovation in reinsurance and capital markets is providing new approaches to transferring public sector exposure). For governments with robust access to international capital markets and capacity to increase revenues, *ex post* borrowing may be the most cost-effective approach to managing public expenditure demands in the aftermath of an earthquake. However, for many others, a damaging earthquake can have significant consequences for public finances requiring governments to devise strategies for managing funding needs, taking into account the timing of expenditures and the relative cost of different funding arrangements. The pooling of earthquake risk across and within countries may offer opportunities for improving access to – and the affordability of – reinsurance coverage for public sector exposures to earthquake.

Ultimately, effective financial management of earthquake risk requires governments to consider the best-use of their limited resources, taking into account the cost and benefits of different approaches including incentives created by different interventions. In particular, governments need to examine causes of under-investment in risk reduction, which is prevalent in most countries, and the best means to correct this imbalance. Achieving this will require effective coordination across government departments and different levels of government, along with strong leadership aimed at addressing the financial vulnerabilities created by earthquake risk.

This report consists of six chapters. Chapter 2 provides an introduction to the prevalence of earthquake risk and implications in terms of the financial management of that risk. Chapter 3 provides an overview of the nature of earthquake risk, describes trends in frequency and severity, and outlines the role of insurance in reducing economic disruption. Chapter 4 provides an overview of the public and private insurance approaches implemented across countries and the relative level of underinsurance of earthquake risk. Chapter 5 outlines options for addressing underinsurance of earthquake risk, including both measures to encourage demand for earthquake insurance and to facilitate the supply of earthquake insurance. Chapter 6 considers issues related to managing the fiscal costs of earthquakes.

This report benefited from responses to a survey questionnaire received from 31 countries: Afghanistan, Albania, Austria, Canada, Chile, Colombia, Costa Rica, Finland, France, Germany, Hungary, Iceland, Japan, Laos, Latvia, Luxemburg, Macedonia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Portugal, Russia, Serbia, Spain, Sri Lanka, Switzerland, Chinese Taipei, Turkey and the United States.[1]

Notes

1 Finland, Laos and Luxemburg provided responses to the questionnaire indicating that their countries do not face any significant earthquake risk. The report also includes information provided in a survey response from the Romanian Insurance Pool against Natural Disasters (PAID).

Chapter 2.

The prevalence of earthquake risk

This chapter provides a brief overview of recent earthquakes and the implications of earthquakes in terms of the financial management of disaster risks.

Earthquakes are among the most costly of natural perils and a number of regions around the world are prone to damaging earthquake events. Since 2016, damaging earthquake events have occurred in all corners of the globe with significant impacts on people, buildings and infrastructure, including:

- In January 2016, a magnitude 6.7 earthquake hit Imphal, the capital of the Indian state of Manipur, killing a dozen people and injuring hundreds more in India and Bangladesh (Yara, 2016).
- A magnitude 6.4 earthquake in Chinese Taipei on 6 February 2016 caused 117 deaths, mostly due to the collapse of a 17-story residential building, and led to USD 750 million in economic losses (Swiss Re, 2017).
- Japan's Kumamoto prefecture was impacted by earthquakes on 14 April 2016 (magnitude 6.2) and 16 April 2016 (magnitude 7.0), leading to approximately 170 000 destroyed or damaged buildings and causing close to USD 30 billion in economic damages and losses (Aon Benfield, 2016a; Swiss Re, 2017).
- A magnitude 7.8 earthquake in Ecuador on 16 April 2016 (one of the two strongest earthquakes recorded in 2016) killed 673 people and damaged or destroyed approximately 37 000 buildings, causing approximately USD 4 billion in economic losses (Swiss Re, 2017).
- A 5.5 magnitude earthquake struck southern Peru on 14 August 2016 and caused damage to approximately 2 600 homes and 13 schools (Aon Benfield, 2016b).
- Italy was affected by several damaging earthquakes in 2016, including a severe 6.2 magnitude earthquake that impacted central Italy on 24 August, which led to 299 deaths, left more than 4 000 people homeless as buildings collapsed and caused an estimated EUR 7.1 billion in economic losses, of which approximately EUR 108 million was insured (Aon Benfield, 2016b; Swiss Re, 2017; Insurance Journal, 2017a). A series of earthquakes in the same region in late October caused a further EUR 6.5 billion in economic losses and EUR 208 million in insured losses (Insurance Journal, 2017b). The same general region was also affected by a series of earthquakes and aftershocks starting 18 January which led to an avalanche that caused 29 deaths (from the earthquake and avalanche).
- A 5.8 magnitude, induced earthquake on 3 September 2016 in Pawnee, Oklahoma was the strongest earthquake ever recorded in the state and led the oil industry regulator to call for the closing of 37 wastewater disposal wells (Pontbriand, 2016).
- A 5.9 magnitude earthquake in Tanzania on 10 September 2016 led to 21 deaths and close to 20 000 destroyed or damaged buildings causing USD 300 million in economic losses (Swiss Re, 2017).
- A 7.8 magnitude earthquake hit near Kaikoura in the northern part of New Zealand's South Island on 14 November 2016, leading to a tsunami and coastal uplift and causing close to USD 4.2 billion in economic losses and 2 deaths (Swiss Re, 2017).
- The Philippines was affected by a series of earthquakes in 2017, including a 6.7 magnitude earthquake near Surigao City on 10 February that killed at least eight people and injured 200 others (Aon Benfield, 2017a), a swarm of

earthquakes in Batangas province starting in April 2017 (including a 6.2 magnitude earthquake on 11 August) and a 6.5 magnitude earthquake on Leyte Island on 6 July.

- A 6.3 magnitude offshore earthquake affected the Greek island of Lesbos on 12 June 2017 leading to one death and several injuries. In the village of Vrisa, approximately 90% of buildings sustained severe damage (Aon Benfield, 2017b). On 20 July 2017, a 6.7 magnitude earthquake struck in the Mediterranean Sea between Turkey and Greece causing two deaths and approximately 500 injuries on the Greek island of Kos (Pontoriero, 2017).
- A magnitude 6.5 earthquake in the Sichuan province of China on 8 August 2017 led to at least 25 deaths and extensive damage to residential and commercial buildings, affecting approximately 72 500 homes (Aon Benfield, 2017c).
- An offshore magnitude 8.1 earthquake affected southern Mexico on 7 September 2017, causing at least 96 fatalities and substantial damage across southern Mexico and Guatemala, particularly in the Mexican states of Chiapas and Oaxaca where an estimated 55 000 homes were damaged (Sherman, 2017; Aon Benfield, 2017d). This was followed by a magnitude 7.1 earthquake south of Mexico City on 19 September that claimed more than 330 lives and caused at least 44 buildings to collapse in Mexico City (Aon Benfield, 2017e). Preliminary estimates of damage caused by the two earthquakes were upwards of USD 2 billion (Insurance Journal, 2017c). A magnitude 6.1 earthquake also occurred on 23 September 2017 in Oaxaca claiming at least five lives (Jefferson, 2017).
- On 12 November 2017, a magnitude 7.3 earthquake struck northern Iraq causing significant casualties and damage, including more than 200 deaths and 1 900 injuries in Iraq and Iran (Aon Benfield, 2017f). A 6.5 magnitude earthquake off the shore of Costa Rica also occurred on the same day, although with fewer reports of damage and casualties (Cordoba, 2017).
- On 15 December 2017, a magnitude 6.5 earthquake affected Indonesia's Java island, causing at least four deaths and damaging approximately 5 000 homes and multiple other structures (Aon Benfield, 2018a).
- On 14 January 2018, the northern coast of Arequipa, Peru was struck by a 7.1 magnitude earthquake causing two deaths and close to 140 injuries. The earthquake caused damage to more than 2 500 structures (Aon Benfield, 2018b).
- On 6 February 2018, a 6.4 magnitude earthquake struck offshore of eastern Chinese Taipei, causing widespread damage in the city of Hualien, including 17 deaths, 278 injuries and damage to thousands of structures (Aon Benfield, 2018c).
- On 16 February 2018, a 7.2 magnitude earthquake affected Mexico's Oaxaca state causing damage to more than 18 000 structures (mostly cracking) and a widespread power disruption (Aon Benfield, 2018c).
- On 26 February 2018, a powerful magnitude 7.5 earthquake struck Papua New Guinea causing at least 75 deaths and more than 500 injuries. Thousands of structures were destroyed by the ground shaking and subsequent landslides triggered by the earthquake (Aon Benfield, 2018c).

Unlike flood and storm events (which can be significantly affected by climate variability),[1], the frequency of earthquake occurrence is generally stable (although with an increase in induced earthquakes in recent years - see Box 3.1). However, exposure to earthquake risk has increased substantially as a result of population increases in earthquake-prone areas. Population growth combined with rapid urbanisation has led to the accumulation of assets in seismic regions and a substantial increase in built-up areas susceptible to earthquake events.

The main damages from earthquakes result from ground shaking which can affect the structural integrity of buildings (resulting in total collapse where the quality of construction is poor) and also cause disruptions to critical services by damaging infrastructure such as roads, bridges, dams and pipelines. The sudden fault displacement that causes the earthquake can also lead to secondary loss agents, such as tsunamis, while the strong ground shaking may lead to liquefaction and landslides – all of which can increase overall damages and losses related to the earthquake event. While earthquakes are largely a natural phenomenon, human activities related to energy operations (including hydrocarbon extraction, disposal of oil industry wastewater and pumping water to depths for heat extraction) have generated locally damaging earthquakes ("induced earthquakes"), including in areas not previously considered susceptible to seismic activity.

Earthquakes have been responsible for more than 800 000 deaths and have left over 17 million people homeless since 1990, particularly in developing countries. Economic losses from earthquakes have also been significant and six of the ten costliest natural disasters since 1980 have been caused by earthquakes (Munich Re, 2016). The annual average damage resulting from earthquakes (1990-2017) is approximately USD 34.7 billion (OECD calculations based on Swiss Re (2018)).

Governments have various tools to manage the financial impacts of earthquakes, including investments in risk mitigation and public awareness, as well as the use of risk transfer tools to absorb post-disaster costs. A key challenge for governments (in addition to minimising casualties) is determining the most effective and efficient use of public resources for managing earthquake risk. Insurance and other risk financing and transfer tools can make a critical contribution to the effective financial management of earthquake risk by spreading risk across domestic and international (re)insurance and capital markets, and reducing the share of losses absorbed by households, businesses and governments in the aftermath of an earthquake event. However, take-up rates of earthquake insurance are extremely low in many countries, as a result of low levels of risk awareness, affordability concerns and expectations of government compensation (among other factors) - leaving individuals, businesses and governments without financial protection against earthquake damages and losses.

This report aims to support governments and policymakers in their efforts to improve the financial management of earthquake risk and build financial resilience against this risk. It builds on the OECD's analysis and guidance on the development of disaster risk financing strategies, including the *G20/OECD Methodological Framework for Disaster Risk Assessment and Risk Financing* and the *Recommendation of the OECD Council on Disaster Risk Financing Strategies*. This guidance highlights the critical role of inance ministers/finance ministries in understanding their country's financial vulnerabilities to disaster risks, based on a comprehensive assessment of financial exposure relative to the capacity to absorb those risks across all segments of society (including households, businesses, local and regional governments and the financial sector).

Notes

[1] Some research has suggested that there may be a link between climate factors and the occurrence of earthquakes, for example as a result of the impact of an increasing load of sea water (with rising sea levels) on the earth's crust and therefore seismic activity (Basu, 2016).

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Chapter 3.

The nature of earthquake risk and trends in economic impacts

This chapter provides an introduction to the nature of earthquake risk and how earthquakes and secondary perils lead to damages to buildings and infrastructure. It provides an overview of trends in the occurrence of earthquakes and their economic impacts as well as the role of insurance in managing earthquake risk.

Occurrence of earthquakes

Earthquakes can be described as any source of sudden shaking as a result of natural forces or human activities. Most earthquakes result from a rupture and displacement along geological faults[1] although events such as volcanic eruptions,[2] landslides, nuclear tests and mining can also generate strong ground shaking.

Earthquakes can occur anywhere in the world although the majority occur in a band surrounding the Pacific Ocean known as the "Ring of Fire", where fast moving plate boundaries exist on almost all sides. Within the Ring of Fire, the Pacific plate and other smaller ocean plates are "subducting" under (passing below) continental plates (eastern Pacific) creating subduction zones or colliding with other continental plates (western Pacific) creating collision zones. In addition to the Pacific Rim, the Alpide belt (stretching from Indonesia through the Himalayas and into the Mediterranean) is another region of plate collision and strong earthquake activity.

Although most earthquakes are caused by natural tectonic processes, some earthquakes are triggered by human activities such as reservoir impoundment, fluid injection, fluid extraction and mining (see Box 3.1).

The severity or energy release of an earthquake is referenced by a magnitude scale which attempts to measure the energy released at the fault rupture source of an earthquake. The epicentre of an earthquake is the point at the surface above where the fault rupture was initiated, although for the largest earthquakes, the rupture can extend for hundreds of kilometres and therefore the epicentre can give a misleading perspective on where the shaking has been generated. To capture the strength of the ground shaking at a given location, an intensity scale can be used (Dowrick, 2009).

The original Richter magnitude scale, based on the logarithm of the amplitude of the ground vibration adjusted for distance from the earthquake was found unworkable for larger earthquakes and today has been superseded by the Moment magnitude scale, which considers the dimensions of the fault source and the rupture displacement. A one step increase in magnitude corresponds to an increase of approximately 32 times the amount of energy release (Prager, 2009).

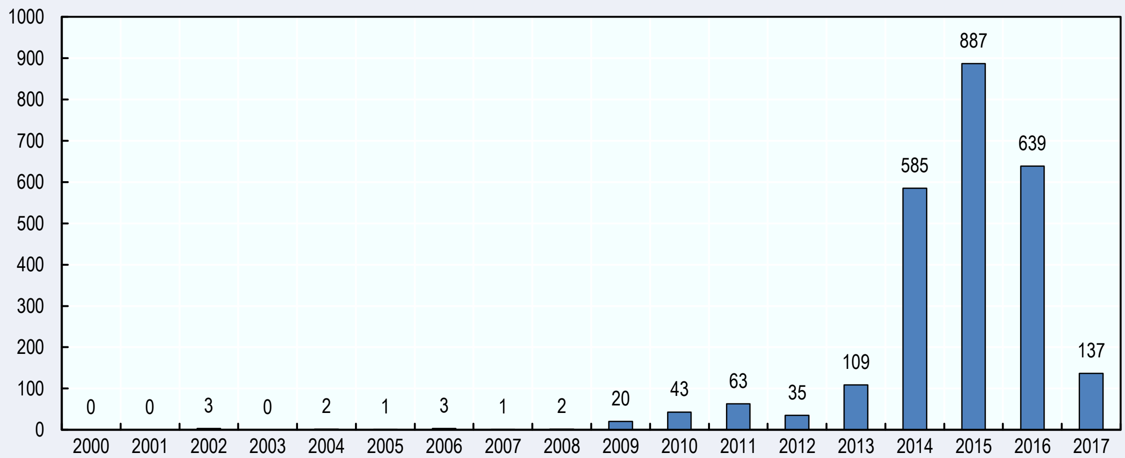
While magnitude measures the release of energy from an earthquake, a measure of shaking intensity is also useful for communicating earthquake impacts. There are several different scales in use including the Modified Mercalli (MM) scale used in the United States, the European Macroseismic Scale (EMS), the Medvedev–Sponheuer–Karnik (MSK) scale used in India, Russia, Israel and other countries and the Shindo scale used in Japan. Structural engineers use parameters such as peak ground acceleration, velocity, or displacement, or consider the overall vibrational spectra of strength and frequency to characterise and measure the earthquake shaking.

A shallow magnitude 2 earthquake is generally the smallest earthquake that can be felt by people while significant structural damage is unlikely to occur as a result of earthquakes with magnitudes of less than 5. According to the United States Geological Survey (USGS) (n.d.) observations since 1990, the annual number of earthquakes above magnitude 5 is approximately 1 500, of which about 18 earthquakes are above magnitude 7 (a level where significant destruction is more likely).

Box 3.1. Induced earthquakes

Parts of central and eastern United States have faced an increase in seismicity in recent years.The average annual number of earthquakes of magnitude 3 and greater has increased from 21 between 1973-2008 to 99 between 2009 and 2013. In Oklahoma, the number of earthquakes of magnitude 3 and greater increased from less than 5 per year before 2008 to a high of 887 in 2015 before declining in 2016 and 2017 (see Figure 3.1). Although most of the earthquakes are in the range of magnitude 3 and 4, there have been some larger events, including a magnitude 5.6 earthquake in Prague, Oklahoma and a magnitude 5.3 earthquake in Trinidad, Colorado (both in 2011). The largest earthquake in the region so far occurred in Pawnee, Oklahoma in September 2016 with a magnitude of 5.8. There is strong scientific evidence that this localised increase in earthquake activity has been triggered by the deep disposal of more than a million barrels a day of wastewater, left over from fracking and conventional oil extraction in the region (Rubinstein and Mahoni, 2015). Raised fluid pressures at depth can reduce the applied stresses across pre-existing loaded faults, effectively lubricating them to failure.

Figure 3.1. Number of earthquakes in Oklahoma (≥ magnitude 3.0).



Note: 2017 is preliminary (as of 4 July).
Source: USGS, 2017.

While not a new phenomenon (a recent study linked earthquakes near Los Angeles in the 1920's to oil and gas operations (Muir-Wood, 2017)), the sharp increase in the frequency of induced earthquakes is putting more people at risk (although there was a notable decrease in the number of events of magnitude 3 or higher in 2016).1 A recent report estimates that 7.9 million people may be subject to induced earthquake risk in the United States and, should the recent increase in the frequency and magnitude of induced earthquakes continue, other locations in Oklahoma, Kansas, Colorado, New Mexico, Texas, and Arkansas could also experience earthquake events (Petersen et al., 2016). According to some estimates, there is currently a 5% to 12% annual probability of a damaging induced earthquake (the chance of having Modified Mercalli Intensity VI or greater) in north-central Oklahoma and southern Kansas (Petersen et al., 2016) - i.e. an intensity already experienced in Oklahoma at least three times since 2010.

Induced earthquakes have also occurred in other parts of the world, often leading to the cessation of the suspected causal activities. A series of earthquakes in the Valencia region of Spain in 2013 were linked to an underground gas storage facility, culminating in a magnitude 4.3 earthquake that led to the closure of the facility (Grigoli and Weimer, 2017). In the Netherlands, a major oil and gas company was recently found liable for the emotional distress of local residents affected by a series of small earthquakes linked to gas drilling (Insurance Journal, 2017). In the United Kingdom, a fracking operation was closed following tremors in 2011 (Twidale, 2017). The largest reported induced earthquake (magnitude 7.9) occurred in China in 2008 as the result of the impoundment of a reservoir (Seismological Society of America, 2017).

1. The frequency of induced earthquakes in the United States declined in 2016 by approximately 25% relative to 2015 along with estimates of future risk. This may be the result of the declining use of wastewater injection methods as new regulatory requirements have been imposed and as the economics of this extraction method has changed with declining prices for oil and gas (Bolton, 2017).

Sources of earthquake damage

The intensity of ground shaking at a site will depends on the distance to the earthquake fault rupture source, seismic wave attenuation and site soil amplification effects. A large earthquake fault rupture, as on a plate boundary subduction zone, may have a depth of 30-40km and hence give lower levels of ground shaking than a far smaller shallow crustal fault rupture close to the coast. However the larger the area of fault rupture, the longer the duration of the earthquake, leading to more energy that is radiated at long periods and a greater potential for damage to large structures such as tall buildings and bridges. The nature of the ground conditions (site soil) is also important. An area underlain by thick soils (sand, clay, or other unconsolidated materials) is likely to experience higher amplitudes of ground shaking than an area underlain by rock.

When a building shakes during an earthquake, the base of the building typically moves in unison with the ground in both lateral and vertical motions. The entire building and its contents above the base experience inertial forces that push them back and forth, up and down. If the shaking force exceeds the strength capacity of the building structure, the building may suffer structural damage or even collapse. Non-structural items in the building that are not sufficiently restrained typically slide, swing, rock, strike other objects or overturn during an earthquake (FEMA, 2012). Most newer building codes have been designed to prevent collapse in the event of a large earthquake although usually not the possibility of extensive damages (Heriot Watt University, 2017) (see Chapter 5). Damages to pipelines or roads can also occur as a direct effect of fault rupture (Sucuoglu and Akkar, 2014) or from landslides that will be particularly prevalent after a large earthquake in mountainous terrain.

Earthquake vibration can also lead to the liquefaction of water saturated in unconsolidated sandy soils. The shaking causes the particles of sand to pack together more tightly pressurising the water and causing the soil to behave like a fluid mass. Foundations of buildings may sink into the ground, while if there is a slope, the upper layer of soil will slump downhill potentially causing severe structural damage to overlying buildings. Liquefaction can also cause damage to underground infrastructure such as water and sewage pipes (Swiss Re, 2014). For example, after the Christchurch earthquakes in New Zealand in 2010/2011, entire neighbourhoods were exposed to liquefaction damage which required that many properties had to be relocated while land in other areas had to be restored in order to be able to support the weight of reconstructed homes (Swiss Re, 2012).

Where large sudden fault displacement occurs beneath the sea, it can displace huge volumes of water and trigger a tsunami, flooding the neighbouring coastline within tens of minutes of the original earthquake. A recent example was the tsunami waves generated by the Great East Japan Earthquake in 2011 which reached 13 to 15 metres high on the adjacent coastline of Honshu over a distance of more than 400 km. The 2004 Indian Ocean tsunami, generated by a 1200km long subduction zone fault rupture and associated with a magnitude 9 earthquake, was one of the most destructive disasters of the 21st century and killed nearly 250 000 people (Rinard Hinga, 2015).

Another significant secondary consequence of earthquakes is fires, which are often triggered by fallen cooking or heating equipment. As a result of earthquake events, emergency response to fire is often exacerbated by the inability of fire crews to pass through blocked city streets or employ water systems which may be disabled by liquefaction. While there are ways to reduce ‘fire starts’ (e.g. automatically shutting off gas supplies), the fires in the city of Kobe Japan in 1995 highlight that these secondary consequences have not been fully mitigated.

Finally, earthquakes can generate aftershocks that may lead to further damage, particularly where the structural integrity of buildings has already been compromised by the initial earthquake. The extremely damaging magnitude 6.3 earthquake that occurred directly beneath the city of Christchurch in February 2011 was one of many aftershocks from the larger magnitude 7.1 earthquake in September 2010. However, as the main shock occurred tens of kilometres from the city it caused far less damage than the February 2011 aftershock (Swiss Re, 2012). Aftershocks may also sometimes be even larger than the original earthquake, as occurred in Italy in autumn 2016.

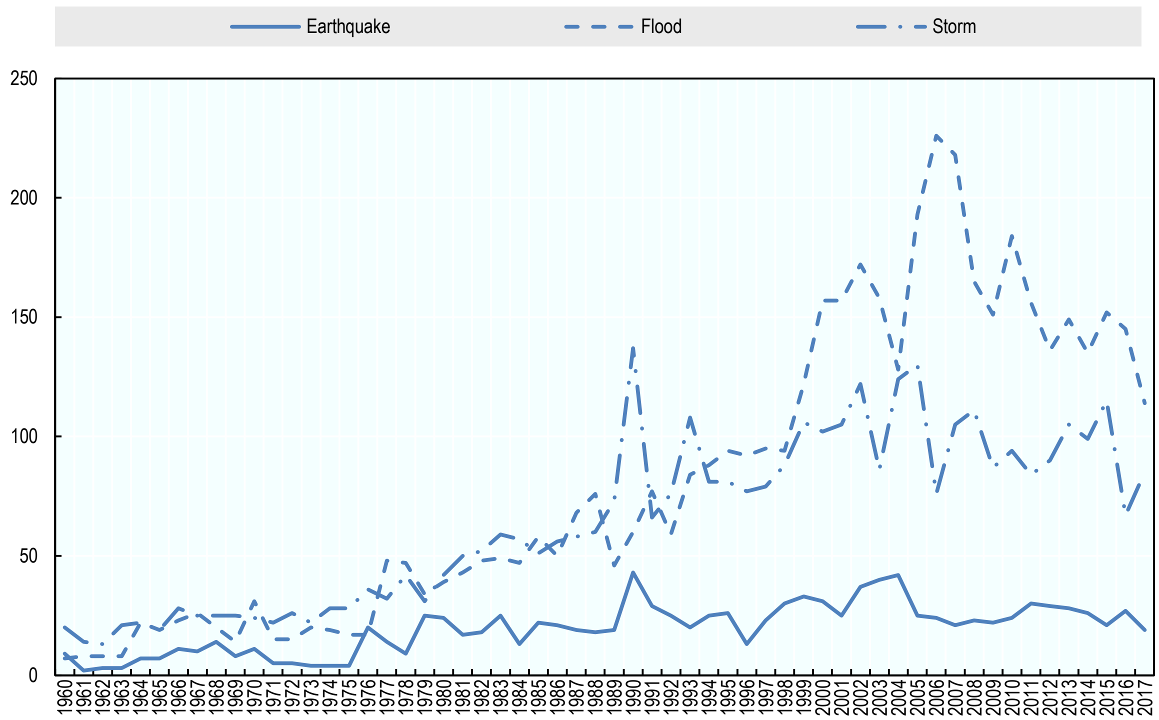
Trends in the occurrence and impact of earthquake events

Damaging earthquakes (i.e. those that meet the criteria for inclusion in the EM-DAT disaster database)[3] occur less frequently than other major disasters, such as floods and storms (see Figure 3.2). The frequency of damaging earthquakes has remained relatively stable during the last four decades. According to EM-DAT data, the annual number of damaging earthquakes has ranged between 20 and 35 in most years (with an annual average of 27 since 1990).

There are 761 earthquakes listed in the EM-DAT database between 1990 and 2017. More than 70% of all damaging earthquakes occurred in thirteen countries (China, Indonesia, Iran, Turkey, Japan, Afghanistan, Pakistan, Peru, the Philippines, Mexico, Greece, Colombia, United States, Italy, India, Colombia, Tajikistan, Tanzania, Russia and Costa Rica). China, Indonesia and Iran are the countries that have been most frequently affected by damaging earthquakes (16%, 10% and 8% of all damaging earthquakes, respectively) (see Figure 3.3).

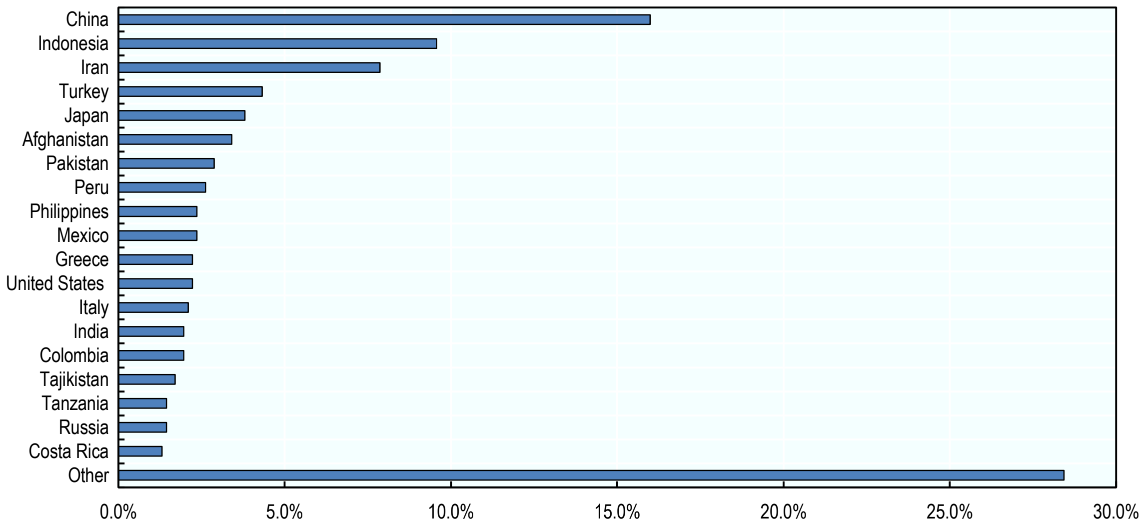
Based on EM-DAT data, the average annual number of deaths from earthquakes between 1990 and 2017 is approximately 29 000. Since 2000, the average annual number of deaths from earthquakes has been higher (just under 40 000), driven by the exceptional death tolls resulting from the 2004 Indian Ocean earthquake and tsunami event and the Haiti earthquake in 2010 (see Figure 3.4). In addition to the significant death toll, earthquakes can affect the well-being of millions of people, particularly when they strike highly-populated areas. For example, the Sichuan earthquake in China in 2008 reportedly affected[4] approximately 50 million people given the relatively high population density in the area impacted.

Figure 3.2. Number of storm, flood and earthquake events: 1960-2017



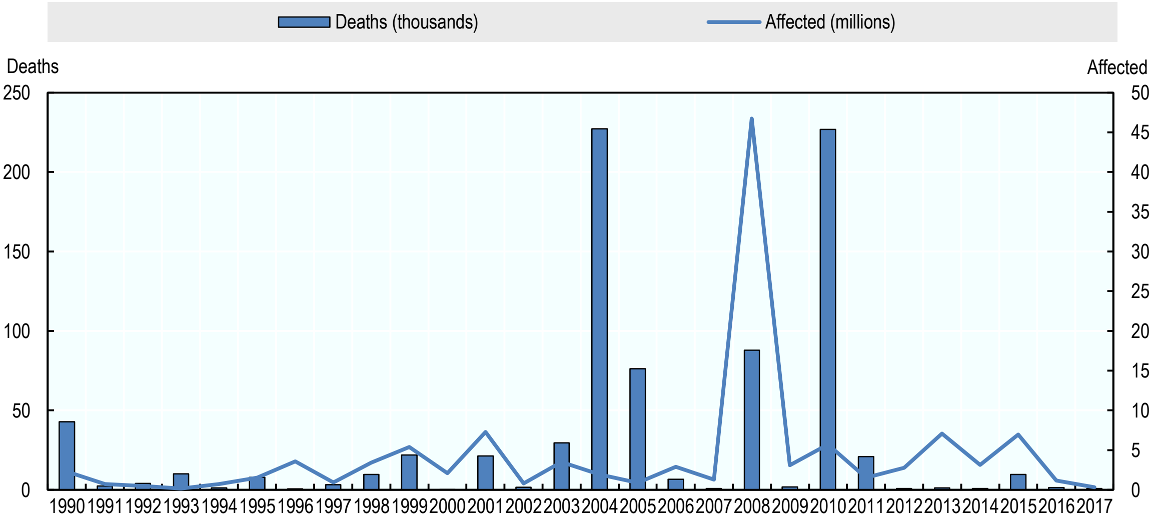
Source: EM-DAT (Centre for Research on the Epidemiology of Disasters' Emergency Events Database).

Figure 3.3. Distribution of earthquake events across countries: 1990-2017 (%)



Source: EM-DAT.

Figure 3.4. Number of deaths and affected people from earthquake events: 1990-2017



Source: EM-DAT.

Lower middle income and low income countries have accounted for approximately 95% of all earthquake-related deaths and 87% of all people affected by earthquake events, likely as a result of higher relative levels of vulnerability (see Figure 3.5).

Figure 3.5. Earthquake events, deaths and affected people by income classification: 1990-2017

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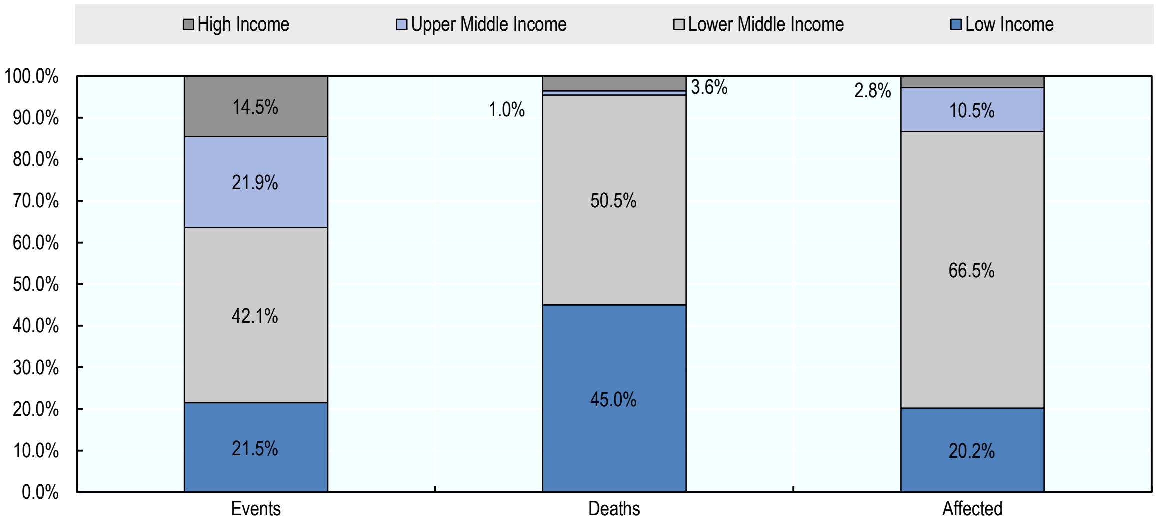


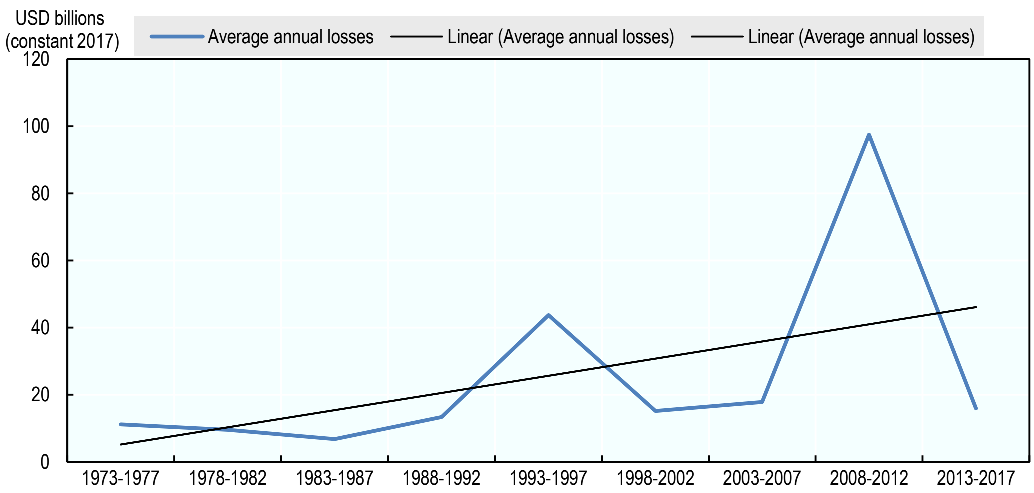
Note: The categorisation of countries by income level is based on World Bank country and lending groups for the year of occurrence.
Source: EM-DAT.

The economic impacts of earthquakes

Earthquakes can lead to significant economic losses (i.e. damages to buildings and infrastructure and business interruption directly resulting from that damage). According to Munich Re (2016), 6 of 10 costliest natural disasters (in terms of overall losses) for the period 1980-2015 were caused by earthquakes. The 2011 Great East Japan Earthquake was the costliest earthquake with USD 210 billion in economic losses followed by the Hanshin-Awaji earthquake (Kobe earthquake) in 1995 with USD 100 billion in economic losses.

Despite the relative stability in the occurrence of earthquakes, there has been an increase in economic losses due to earthquake over time (see Figure 3.6). The average annual losses from earthquakes has increased from approximately USD 11 billion between 1972 and 1976 (in constant 2016 USD) to almost USD 17 billion per year between 2012 and 2016 (and USD 92 billion between 2007 and 2011). Since 1990, earthquakes have caused average annual economic losses of approximately USD 34.5 billion (in constant 2016 USD).

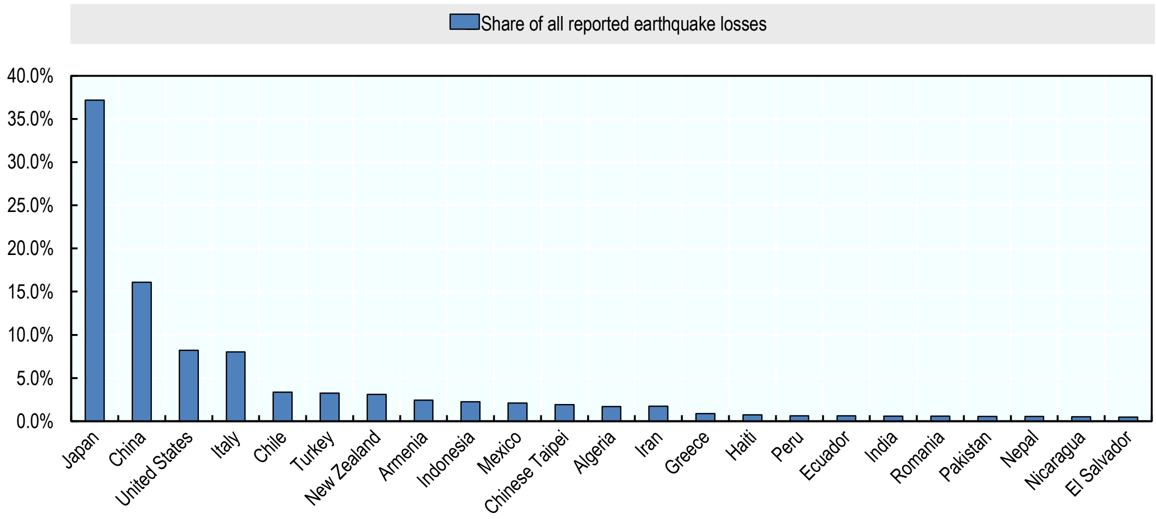
Figure 3.6. Average annual losses from earthquake events: 1973-2017



Source: OECD calculations based on Swiss Re (2018) estimates of total economic losses inflated to 2017 USD.

Since 1970, earthquakes have led to the most economic losses in Japan (which accounts for almost 40% of all reported earthquake losses), followed by China, the United States and Italy. Overall, seven countries have accounted for close to 80% of all reported earthquake losses since 1970 and 23 countries, each with USD 5 billion in cumulative reported economic losses or more since 1970 (constant 2017 USD), have accounted for just under 98% of all reported earthquake losses since 1970 (see Figure 3.7).

Figure 3.7. Distribution of earthquake losses across countries: 1970-2017



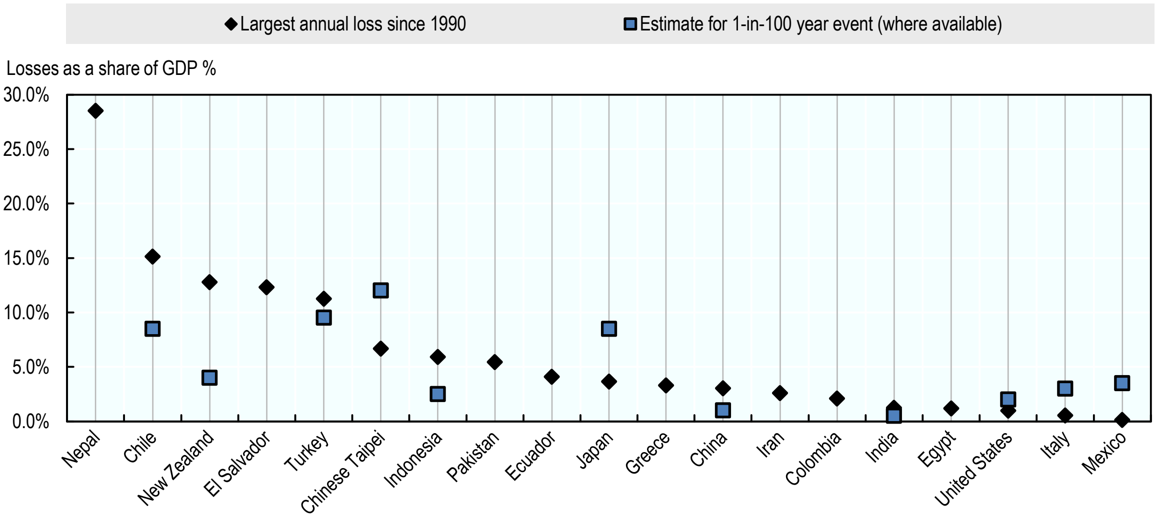
Source: Swiss Re (2018) estimates of total economic losses inflated to 2017 USD.

While past events have led to significant economic losses, many countries have not faced the level of losses they could potentially face based on estimates of their exposure to earthquake risk. The actual annual average (economic) loss (AAL) (as reported by Swiss Re (2018)) for many of the most significantly impacted countries is well below estimates of expected AAL from earthquakes (not including tsunamis) provided, for example, by UNISDR (2015): USD 31.8 billion for Japan (relative to actual AAL since 1990 of USD 15.6 billion in constant 2016 USD), USD 14.4 billion for the United States (relative to USD 2.7 billion) and USD 9.7 billion for Italy (relative to USD 1.2 billion).

In many regions, earthquake events of the recent past have not been nearly as powerful or as damaging as modelled severe events, suggesting past losses may not provide a complete picture of potential exposure. For example, there is an estimated 46% probability that a 7.5 magnitude earthquake will strike California (United States) in the next 30 years which is larger than any earthquake event in that region since at least 1970 (Sahabi, Reis and Koram, 2018). The California ShakeOut scenario estimates that losses from a 7.8 magnitude earthquake in Southern California would cause 1 800 deaths and over USD 200 billion in economic losses (USGS, 2008). A magnitude 9 Cascadia earthquake (return period of between 400 and 600 years), affecting the Northwestern United States and Western Canada would cause an estimated USD 174 billion to USD 186 billion in losses according to RMS and AIR models (as reported in a recent Bank of England (2017) stress test scenario), in a region that has not faced an earthquake larger than 6.8 magnitude in at least 70 years (Swiss Re, 2018).

Large earthquake events can cause damages equivalent to a significant share of GDP (see Figure 3.8). In Haiti, for example, the 2010 earthquake caused economic losses equivalent to 130% of GDP. In Algeria, the Boumerdès earthquake in 2003 led to economic losses of approximately 116% of GDP. In Turkey, El Salvador, New Zealand, Chile and Nepal, losses resulting from the largest earthquake event since 1990 exceeded 10% of GDP. In many other economies (e.g. Chinese Taipei, Japan, Mexico), a modelled l-in-100 year event would cause more substantial losses as a share of GDP than what has occurred since 1990.

Figure 3.8. Earthquake damage as a share of GDP



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Source: Data on total economic losses for the largest event since 1990 is from Swiss Re (2018) and GDP figures (current prices in USD for the year of the event) are from the IMF (2017). The estimates of losses as a share of GDP for a 1-in-100 year event are from Swiss Re (2016).

Given the relative stability in the frequency of major earthquake events, the increase in earthquake losses in recent years (as well as the estimates of significant potential exposure to earthquake damage) is likely the result of socio-economic development and the accumulation of assets in earthquake-prone areas, particularly in urban areas. Allen (2007) calculated the seismic exposure of the world's 30 largest urban centres and found that the number of cities exposed to moderate to high seismic risk increased from 10 in 1950 to 16 by 2000. An analysis by Swiss Re (2016) estimates that close to 140 million people in 10 earthquake-prone cities could potentially be affected by a significant event (Tokyo-Yokohama, Jakarta, Manila, Los Angeles, Osaka-Kobe, Tehran, Nagoya, Lima, Taipei and Istanbul). According to Lloyd's (2015), USD 464.7 billion of economic output is at risk from earthquakes in 301 cities analysed, including more than USD 15 billion in each of the seven most exposed cities (Lima, Tehran, Istanbul, Taipei, Tianjin, Tokyo and Los Angeles). In the United States, FEMA's National Earthquake Hazard Reduction Program (NEHRP) estimates that annualised earthquake losses (AEL) are approximately 6.1 billion USD with economic exposure (building stocks and contents) of 59 trillion USD, concentrated in fifty-five major metropolitan areas that account for 80% of the total AEL (FEMA, 2017).

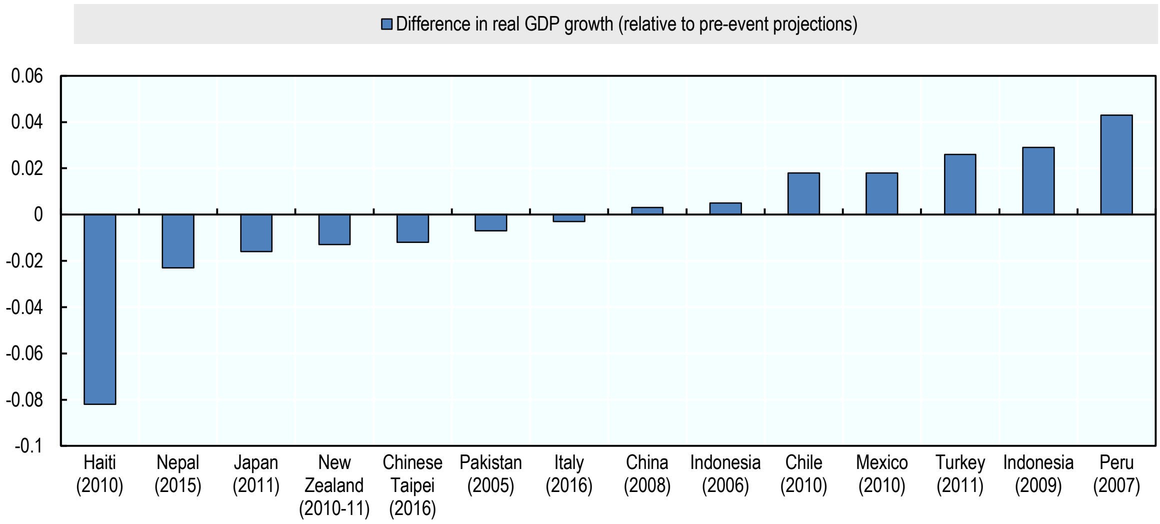
In addition to the direct damages to buildings, infrastructure, equipment and contents/inventories, earthquakes can also lead to a number of indirect losses. Indirect losses to business (or business interruption) are the losses in the value added component of goods and services that are not produced (or produced at a higher cost) as a result of the impacts of earthquakes. For example, a study of the impact of the Northridge earthquake in the United States in 1994 on 1 100 affected businesses found that more than half of the surveyed businesses were forced to close for at least some period due to the earthquake and that the median duration of the interruption was approximately two days (Tierney, 1997). In addition, nearly 60% of respondents reported that their employees were unable to get to work, 40% faced a decline in customer traffic and 23% reported difficulties related to the delivery of their goods and services - all of which would be expected to increase production costs.

Indirect losses can also result from supply chain disruptions or disruptions to critical services (normally considered to be contingent business interruption losses) which can have both national and international impacts. For example, in the first half of 2011, Japanese car manufacturing output was approximately 30% less than in the same period the prior year, partly as a result of disruptions at suppliers directly affected by the Great East Japan Earthquake (automobile production in the United States was also affected in the second quarter of 2011 given the dependence on crucial parts from Japan (Ranghieri and Ishiwatari, 2014)). Large businesses in Japan were also impacted by government imposed restrictions on the supply of electricity (businesses that had a supply of 500 kilowatts or more directly from the Tokyo Electric Power Company were limited to a maximum of 85% of their previous year's hourly electric power consumption (Umeda, 2013)). In extreme cases, an earthquake could also lead to stress in the financial system. For example, an earthquake that leads to significant uninsured damages to a region’s housing stock could leave many households with a strong incentive to default on their mortgage debt with potentially serious consequences for the banking sector (IBC, 2014).

A major earthquake can also have serious implications for public finances. There will likely be a need for a (potentially unexpected or unfunded) fiscal outlay to address emergency response, recovery and reconstruction needs as well as a decline in tax revenues. For example, to support recovery and reconstruction after the Great East Japan Earthquake, the Japanese government approved three supplementary budgets in 2011 totalling JPY 15 trillion (Ranghieri and Ishiwatari, 2014). The Northridge earthquake in the United States in 1994 caused a USD 0.86 billion decline in local, state and federal tax revenue due to business interruption (Petak and Elahi, 2000).

Direct damages, together with the reduction in production (business interruption), can impact economic growth. Von Peter, Von Dahlen and Saxena (2012), using data for 2 476 major natural catastrophes in 203 countries between 1960 and 2011 found that the average natural disaster (including earthquakes) leads to a fall in growth of 1.0% of GDP upon impact and a cumulative loss to GDP of 2.6%. Earthquake specific studies have mixed results in terms of their findings on the macro-economic impact of earthquakes. An analysis by Standard & Poor's (2015) (using Swiss Re data on expected losses) found that GDP per capita would be lower in all but one of the examined countries five years after a 1-in-250 year earthquake event. In some countries, including Chile, Costa Rica, Japan, Panama, Peru, the Philippines, Chinese Taipei and Turkey, the decline in GDP per capita is estimated at more than 5%. Many studies of actual events (see Raddatz, 2009; Loayza et al., 2009; Fomby, Ikeda and Loayza, 2009) do not find any significant impact (negative or positive) of earthquakes on economic growth, although some studies, such as Skidmore and Toya (2002), found a decline in economic growth as a result of earthquakes. This may be explained by offsetting economic impacts as the negative impacts of direct damages and production losses in many sectors may be counterbalanced by increased activity in other sectors of the economy that may benefit due to reconstruction activities (e.g. construction sector). In addition, the capital investment to replace damaged equipment and machinery with new (potentially more productive) equipment and machinery could support future economic growth. Figure 3.9 provides an illustration of the impact of recent earthquakes on economic growth by comparing pre-event economic projections with actual post-event economic outcomes.

Figure 3.9. The economic impact of recent earthquakes



Source: IMF World Economic Outlook (various years).

Employment levels can also be impacted by earthquake events. While earthquakes can lead to an increase in the employment level in some sectors, such as construction and health, severe earthquakes have usually resulted in a decline in overall employment levels. For example, there was an 8% decline in total employment in New Zealand approximately six months after the Canterbury earthquakes (2010/2011), despite an 18% increase in construction employment. Leisure sectors (accommodation, food services) and retail faced large declines in employment while there was also a significant decrease in labour force participation, potentially suggesting dislocation in the aftermath of the earthquakes (New Zealand Parliamentary Service, 2011).

In addition, large events might have implications for financial markets (e.g. stock markets, foreign exchange markets). While financial markets generally respond negatively to shocks such as major earthquakes, leading to depreciation of the national currency and a decline in stock markets, there may be other offsetting factors. For example, in cases where significant levels of international reinsurance has been acquired (and therefore an influx of foreign capital is expected) or where foreign goods and services are expected to play a large role in reconstruction, there could be an increase in demand for domestic currency and potentially currency appreciation. There may also be offsetting positive impacts on stock prices, such as the expectation of increased economic activity as a result of reconstruction. These kinds of counteracting forces have led to varied findings on the impact of past major earthquakes on insurance company stock prices (see Box 3.2).

Box 3.2. Impacts of earthquakes on equity prices of insurance companies

In theory, insurance companies, and in particular property and casualty insurers, would expect to be negatively affected by an earthquake due to the claims payments they will need to make to cover insured losses. These payouts would normally have a negative impact on profitability and should lead to downward pressure on insurance company equity valuations. However, the occurrence of an earthquake could lead to an increase in expected demand for insurance coverage, with positive implications for future insurance company profitability. This net positive impact was described by Shelor, Anderson and Cross (1992) as "gaining from loss hypothesis".

Some studies have examined the impact of major earthquakes and disasters on the equity price performance of insurance companies with varied findings. Shelor, Anderson and Cross (1992) analysed the impacts of the Loma Prieta (California) earthquake in 1989 on insurance companies and found a significant increase in stock prices during the two days after the earthquake event.

On the other hand, Yamori and Kobayashi (1999) and Bolak and Suer (2008) found a significant negative impact on insurance companies' equity prices following the Hanshin-Awaji (Japan) earthquake in 1995 and the Marmara (Turkey) earthquake in 1999, respectively. The finding for the Marmara earthquake was confirmed by a more recent study by Yilmaz and Karan (2015) which also found negative impacts for insurers. Yilmaz and Karan also looked at the 1998 Ceyhan and 2011 Van earthquakes in Turkey although found no significant impacts from those smaller earthquakes, which occurred in less industrialised regions of Turkey. Takao et al. (2013) examined the impact of the Great East Japan Earthquake and did not find significant positive (or negative) impacts on equity prices of insurance companies which they concluded was partly the result of the stabilising role of the Japan Earthquake Reinsurance (JER) scheme.

The role of insurance in reducing economic disruption

Some of the variation in terms of the impact of major earthquakes on economic activity may be related to different levels of insurance coverage in affected countries. In general, higher levels of insurance penetration have been found to reduce the negative impact of disasters on economic output. Melecky and Raddatz (2011) estimate the impact of geological, climatic, and other types of natural disasters on government expenditures and revenues by using data for high and middle-income countries between 1975 and 2008. They found that countries with lower levels of insurance penetration faced larger declines in economic output and more considerable increases in fiscal deficits than countries with higher levels of insurance penetration. Similarly, von Peter, von Dahlen and Saxena (2012) estimate the relative impact of disaster events for a fully insured or uninsured economy. They find that insured losses have no statistically significant impact on long-term output (i.e. GDP growth does not diverge significantly from its pre-disaster trend) while uninsured losses cause a cumulative output cost over 10 years of 2.3% or more. A more recent study by Standard and Poor's (2015) found that 50% insurance coverage of assets would reduce the impact of a major disaster (i.e. a disaster damaging 5% of all assets) on growth by 40% relative to a scenario with no insurance coverage.

Insurance indemnity payments after an earthquake can provide quick compensation to households and businesses (Keating et al., 2014) to repair or reconstruct damaged buildings, replace possessions, machinery and equipment and, where business interruption insurance coverage was purchased, compensate for losses due to disrupted production - thereby reducing the economic disruption caused by the event. Higher levels of insurance penetration for earthquake risk can also reduce the impact of earthquakes on public finances by potentially lowering the need for government compensation of losses incurred by households and businesses (and providing the government with greater flexibility to direct recovery spending towards mitigating economic impacts). A Lloyd's (2012) case study of five disasters, including the Sichuan earthquake in China in 2008 and the Great East Japan Earthquake in 2011, found that a larger share of uninsured losses tended to be correlated with a larger overall cost to taxpayers. This is likely because governments faced with significant uninsured private losses after a disaster would face political pressure to compensate those affected, leading to negative impacts on public finances (in cases where that compensation was not previously accounted for in public accounts).

In countries with low levels of insurance protection against earthquakes, a significant share of the costs of repair, reconstruction and replacement will be borne by households and businesses (or governments, if compensation for these losses is provided). The financial burden on households and businesses is likely to lead to reduced consumption and investment. In extreme cases, the extra financial burden on households and businesses could have financial stability implications through an increase in defaults on mortgages, consumer and/or commercial loans if debtors are faced with costs that are beyond their financial capacity. Following the Great East Japan Earthquake, some households and businesses were forced to obtain secondary loans against their residential and commercial properties, on top of existing mortgage loans, in order to finance these costs (Ranghieri and Ishiwatari, 2014).

There are a number of reasons why the financial impacts of earthquakes may be most efficiently managed by insurance (and capital) markets. Insurance companies are able to accumulate funds through the collection of premiums in order to create reserves for paying out future losses. By providing coverage for other uncorrelated perils (including other catastrophe perils such as floods, cyclones or droughts), they can also diversify their exposure to earthquake risk within larger pools of accumulated premiums (Wang, Lin and Walker, 2009). The transfer by insurance companies of some of their earthquake exposure to international reinsurance and capital markets can further diversify the risk and reduce the impact of earthquake losses on the domestic economy. For example, 95% of insured losses incurred as a result of the Maule earthquake in Chile in 2010 were reinsured in international markets (Aon Benfield, 2011) which likely reduced the overall level of economic disruption from what was one of the largest ever recorded earthquake events.

Finally, where insurance premiums are risk-based (and risk reduction is rewarded with lower insurance premiums), insurance can also provide an important incentive for *ex ante* risk mitigation actions which could reduce the overall level of damage from major earthquake events.

Notes

1. Tectonic forces are the major sources of earthquakes. Most of the earth's seismic energy is released in the vicinity of the plate boundaries and are known as inter-plate earthquakes. Earthquakes can also occur within plates, although less than 10% of all earthquakes occur within plate (intraplate) interiors. Intraplate earthquakes can be found on nearly every continent.

2. Smaller earthquakes can also be found in the vicinity of active volcanoes, generated by underlying movements of magma and can also serve as an early warning of volcanic eruptions (Foxworthy and Hill, 1982).

3. The EM-DAT database, maintained by the Centre for Research on the Epidemiology of Disasters, provides data on deaths, affected people, damages and other variables for natural and man-made disasters in countries since 1900. To be included in the EM-DAT database, a disaster must meet at least one of the following criteria: (i) ten or more people reported killed; (ii) one hundred or more people reported affected; (iii) a declaration of a state of emergency; or (iv) a call for international assistance.

4. "Affected" people are defined in EM-DAT as those that require "immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance."

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Chapter 4.

Insurance coverage for earthquake risk

This chapter provides an overview of insurance coverage available for earthquake risk in different countries. It describes public (re)insurance schemes that have been established to provide coverage for earthquake (and sometimes other natural peril) risks, as well as coverage available from private insurance companies. The chapter also outlines the significant level of underinsurance for earthquake risk and some of the main causes of underinsurance.

Insurance coverage for earthquake risk may be offered as a standard inclusion in residential and commercial property policies, as an automatic or optional extension (or endorsement) to these policies, or as a stand-alone policy that may be purchased independently. This coverage may be offered by private insurance companies or through public insurance schemes, or some combination of both. In a number of countries (including many with significant exposure to earthquake risk), specific insurance or reinsurance schemes, supported by governments or as an initiative of the insurance sector, have been developed to provide basic, or more comprehensive, coverage against earthquake risks, sometimes bundled with coverage for other natural catastrophe perils and usually limited to providing coverage for residential property. In other countries, including those with relatively lower earthquake exposure, private insurance companies are the main suppliers of earthquake coverage. A description of insurance arrangements for earthquake risk and an indication of earthquake insurance penetration levels (where available) for 34 OECD and non-OECD economies is provided in Table 4.1.

Table 4.1. Insurance arrangements for earthquake risk

Country	Form of coverage		Description
	Automatic extension	Optional Add-On	
Albania			Private insurance coverage for earthquakes and other natural perils is normally included in fire insurance policies and sometimes required as a condition of mortgage and/or other credit operations. Stand-alone coverage for earthquake risk, backed by Europa Re, is also distributed by a number of private insurers. An estimated 2% of properties are covered by fire (and earthquake) insurance (Dengeri, 2015).
Australia			Private insurance coverage for earthquakes and tsunami is normally included in residential property insurance policies and as a standard extension to commercial property insurance policies. This has led to high-levels of insurance coverage for earthquake risk (Walker, 2008).
Austria			Insurance coverage for earthquakes (and many other natural perils) is not included in standard property policies offered by private insurers although coverage can be added (usually in combination with other natural perils). An estimated 5%-10% of overall sum insured is covered for earthquake risk.
Belgium			Insurance coverage for earthquakes and other natural perils is included in standard property insurance policies provided by private insurers. Property insurance penetration is estimated to be above 90% (Insurance Europe, n.d.).
Canada			Earthquake coverage is offered by private insurers as an optional add-on to residential and commercial policies and includes secondary perils, including fire. The penetration of earthquake coverage for residential properties is estimated to be 60% to 65% in Southwestern British Columbia and approximately 2% in Eastern Ontario/Quebec (i.e. Ottawa-Montreal-Quebec City). For commercial properties, penetration is estimated to be 80% to 90% as a result of the widespread purchase of all-risk policies.
Chile			Coverage for earthquake risk from private insurers is provided as an optional add-on to mandatory fire insurance policies although lenders usually require earthquake coverage for properties with mortgages. Approximately 49% of all insured properties in Chile are insured against earthquake risk.
China			Private insurers offer coverage for earthquake risk as an optional add-on to residential and commercial property policies. Basic earthquake insurance coverage for residential property is also available throughout the country at a low premium rate through the companies participating in the China Urban and Rural Residential Building Earthquakes Catastrophe Insurance Pool, a government-promoted catastrophe insurance scheme.
Colombia			Insurance coverage for earthquake risk is offered as an optional add-on to property insurance policies by private insurers. In certain cases, earthquake coverage is mandatory: (i) for properties with mortgage loans; (ii) common areas in immovable properties; (iii) real estate assets of entities supervised by the financial services superintendent; and (iv) securitised real estate assets during the term of the trust contract. For other properties, penetration of earthquake insurance is relatively low.

Country	Form of coverage		Description
	Automatic extension	Optional Add-On	
Costa Rica			Earthquake insurance coverage may be provided as an optional add-on or as an automatic inclusion in property insurance policies by the state-owned insurer and private insurers. Some financial institutions require earthquake coverage for their lending operations. Approximately 27% of residential property and 48% of commercial property is covered against earthquake risk.
France			Residential and commercial property policies automatically include standard coverage for natural catastrophes for which reinsurance is available from a public reinsurer (*Caisse centrale de réassurance*). Over 95% of all residential and commercial properties are covered against earthquake (and other natural catastrophe) perils.
Germany			Coverage for earthquake risk is included in optional "Elementarschadenversicherung" coverage for natural perils that can be added to residential property policies. Overall, approximately 40% of German residential properties have acquired this optional coverage although penetration is higher in earthquake-prone regions. Commercial property policies are less standardised and therefore may include coverage for earthquake risk on a stand-alone or bundled basis.
Greece			Coverage for earthquake risk is available as an optional add-on to residential and commercial property policies. The share of residential properties that are covered against earthquake risk is estimated to be less than 15% (Keep Talking Greece, 2013).
Hungary			Earthquake coverage is bundled with other natural perils and automatically included in residential and commercial policies. Approximately 70% of residential properties and 80% of commercial properties have all-risk insurance coverage, including for earthquake (Dowlen, 2008; Pollner, 2012).
Iceland			Coverage for earthquake and other natural perils provided by a public insurer (Iceland Catastrophe Insurance) is automatically added to mandatory fire insurance policies. Therefore, penetration of earthquake coverage is 100%.
Italy			Coverage for earthquake, volcanic eruption and flood damage is normally excluded from standard residential property insurance policies although is available as an optional extension. Coverage for natural catastrophe perils is commonly included in commercial policies. It is estimated that only 1% of Italian residential properties are covered against earthquake risk (Swiss Re, 2015).
Japan			Earthquake coverage is an optional add-on to residential fire insurance policies offered by private non-life insurers. Non-life insurers are subject to the Earthquake Insurance Act and must cede their earthquake exposure to JER. Approximately 30% of households have acquired earthquake coverage. Private insurers also provide optional coverage for commercial and industrial risks. In addition, cooperative insurers offer earthquake coverage as an optional add-on to residential fire insurance policies. The coverage provided by cooperative insurers is not subject to the Earthquake Insurance Act or ceded to JER.
Latvia			Private insurance coverage for earthquake (and other natural catastrophe) perils is available as an optional add-on to residential and commercial policies. Some financial institutions require earthquake coverage for credit operations. Approximately 20% of all properties are covered against earthquake risk.
Macedonia			Private insurance companies offer coverage for earthquake risk as an optional extension to residential and commercial property insurance policies. Stand-alone coverage for earthquake risk, backed by Europa Re, is also distributed by a number of private insurers. Less than 10% of households in Macedonia have property insurance (Balkan Insight, 2011) and only a small share (7%) of collected premiums is for earthquake coverage.
Mexico			Private insurance companies offer coverage for earthquake (and other natural catastrophe) perils as an optional extension to residential and commercial property insurance policies. Mortgage lenders require properties to be insured, often including insurance against earthquake risk. An estimated 5% of households are covered against earthquake risk (Mexico News Daily, 2015) while coverage rates among commercial entities range from 50% among smaller companies to more than 75% among the larger companies (Insurance Information Institute, 2012).
New Zealand			Earthquake coverage is, in general, automatically included in residential and commercial policies with residential coverage for earthquake risk provided by the Earthquake Commission (EQC). Private insurance companies offer coverage for

Country	Form of coverage: Automatic extension	Form of coverage: Optional Add-On	Description
			commercial risks and excess coverage for households for amounts above EQC limits. Mortgage lenders typically require earthquake coverage on mortgaged properties. Approximately 95% of residential properties and 80% of commercial properties have coverage against earthquake risk.
Norway			Insurance coverage for earthquakes and other natural disaster perils is automatically included in residential property policies offered by private insurance companies. These companies have established a claims pool (a Natural Perils Pool, which is enshrined in legislation) that will payout on natural disaster claims with burden sharing among insurers based on market share.
Papua New Guinea			Earthquake coverage may be offered by private insurers as a standard inclusion or optional extension to residential and commercial policies. The overall share of properties insured is estimated to be around 5% (Oxford Business Group, 2013).
Peru			Earthquake coverage may be offered by private insurers as a standard inclusion or optional extension to residential and commercial policies. While the share of residential properties covered against earthquake risk is relatively small, earthquake coverage was the third largest non-life insurance segment in 2014 by premiums collected (larger than fire insurance) (Lonergan, 2014).
Philippines			Earthquake coverage is offered by private insurers as an optional add-on to residential and commercial policies, bundled with other natural catastrophe perils. An estimated 10% to 20% of buildings are covered against earthquake risk (Torres, 2013).
Portugal			Earthquake coverage is offered by private insurers as an optional add-on to residential and commercial property insurance policies, normally as a fire and other natural damages or multi-risk policy. Most banks ask for insurance coverage for mortgaged properties. A 2008 study found that 16% of residential properties had coverage for earthquake risk although with higher levels of coverage in more seismically-active regions.
Romania			Private insurers distribute the mandatory basic flood, earthquake and landslide coverage provided through the Insurance Pool Against Natural Disasters (PAID) and also offer their own additional earthquake coverage, normally as an automatic inclusion in residential property insurance policies (as well as coverage for commercial property). An estimated 20% of households have earthquake coverage through PAID.
Russia			Private insurers offer coverage against earthquake risk (and other natural catastrophe) perils as an optional add-on to residential and commercial policies. Mortgage lenders will often require earthquake coverage on mortgaged properties. Approximately 65% of insured commercial property is insured against natural catastrophe perils, including earthquake.
Serbia			Earthquake coverage offered by private insurers is normally an optional add-on to residential and commercial property policies although some policies automatically include coverage for earthquake as part of standard policies. Stand-alone coverage for earthquake risk, backed by Europa Re, is also distributed by a number of private insurers. Approximately 5% of residential property is insured against earthquake risk.[1]
Spain			Coverage for earthquake risk is included in the extraordinary risks coverage that is automatically included in all residential and commercial property policies distributed by private insurers and transferred to the *Consorcio de Compensación de Seguros* (CCS). Approximately 75% of all residential property is insured, including for extraordinary risks.
Sri Lanka			A basic amount of public compensation for damages (up to LKR 2.5 million) to residential and commercial (SMEs only) property from natural catastrophe perils, including earthquakes, is available through the National Insurance Trust Fund. Private and public insurance companies offer insurance coverage for earthquake risk, often as a standard inclusion in fire and allied perils coverage.
Switzerland	 (Zurich)		Coverage for earthquake risk is not normally included in the coverage provided by Swiss cantonal monopoles (public building insurers) or in the standardised natural catastrophe coverage provided by private insurers in some Swiss cantons. In the canton of Zurich, earthquake coverage is mandatory and offered by the cantonal monopole. In other cantons, 17 local cantonal monopoles have established a pooling arrangement to provide voluntary compensation for earthquake damage (capacity of up to CHF 2 billion for each of up to two events). A number of private insurers offer coverage against earthquake risk (on a stand-alone basis or as an extension to fire

Country	Form of coverage: Automatic extension	Form of coverage: Optional Add-On	Description
			policies), including a subsidiary of the cantonal monopole insurer for Bern which regulated and supervised as a private insurer. In Zurich canton, the private insurers offer only excess coverage beyond the coverage provided by the cantonal monopole. The share of properties covered by optional earthquake insurance (outside of Zurich canton) is approximately 10% (Bertogg, 2017).
Chinese Taipei			Earthquake coverage provided by the Taiwan Residential Earthquake Insurance Fund (TREIF) is automatically included in residential property policies. Additional coverage for earthquake risk (i.e. in excess of the amount covered by TREIF) is available on an optional basis from private insurers. Earthquake coverage for commercial property is provided by private insurers as an optional add-on. Approximately 32% of residential households have earthquake coverage through TREIF.
Turkey			Stand-alone earthquake coverage provided by the Turkish Catastrophe Insurance Pool (TCIP) is required for residential properties located within municipal boundaries. Private insurers offer content and excess building coverage for earthquake risk for residential properties (i.e. above the amount covered by TCIP) and coverage for commercial properties as an optional add-on. Approximately 42% of residential buildings within municipal boundaries are covered by TCIP earthquake policies.
United States			Private insurers offer coverage for earthquake risk as an optional add-on (endorsement) to residential and commercial property policies or as a separate stand-alone policy (although coverage for secondary perils, such as fire and water damage due to burst gas and water pipes, is provided by standard home and business insurance policies in most states). In California, private insurers are required to offer earthquake coverage, either their own coverage or the coverage provided by the California Earthquake Authority (CEA). An estimated 10% of residential properties are covered against earthquake risk with higher rates of coverage in the Western United States (18%).

[1] Based on an estimate of the number of earthquake insurance policies provided in Serbia's response to the OECD questionnaire on the financial management of earthquake risk relative to an IMF (2010) estimate of the number of dwellings in Serbia.
Source: Responses to the OECD questionnaire on the financial management of earthquake risk.

Public insurance schemes

In many countries, governments play a role in the provision of insurance coverage for earthquake risk. In some countries or regions (California,United States), China, Japan, New Zealand, Chinese Taipei, Turkey), schemes have been specifically established to address high-levels of earthquake exposure. In other countries (Albania, France, Iceland, Macedonia, Romania, Serbia, Spain, Switzerland), schemes have been established to address a broader range of natural (or even man-made) perils. In a few other countries (Costa Rica, Sri Lanka), the government's involvement in providing insurance coverage for earthquakes results from government ownership of major insurance companies. Most of the schemes that have been established involve some form of collaboration between governments and private insurance companies.

Schemes focused on earthquake risk have generally been established following a major event that resulted in disruptions to the availability of earthquake insurance and/or revealed a significant level of uninsured earthquake exposure. For example, the New Zealand Earthquake and War Damage Commission (the predecessor to the Earthquake Commission (EQC)) was established following the Wairarapa Earthquake of 1942; Japan Earthquake Reinsurance (JER) was established following the devastation caused by the Niigata earthquake in 1964; the California Earthquake Authority (CEA) came about as a result of insurance market disruptions following the Northridge earthquake in 1994; the Taiwan Residential Earthquake Insurance Fund (TREIF) was created in the aftermath of the Chi Chi earthquake in Chinese Taipei in 1999; and the Turkish Catastrophe Insurance

Pool (TCIP) was developed in the aftermath of the 1999 Marmara earthquake. More recently, the China Insurance Regulatory Commission and the Chinese Ministry of Finance have commissioned PICC P&C, the largest property and casualty insurance company, to establish a China Residential Earthquake Insurance Pool (CREIP) which has begun issuing basic earthquake coverage for urban and rural residents across the country through participating insurers. Other earthquake-prone countries, including Peru and the Philippines, have also been considering the establishment of earthquake insurance schemes to address high-levels of uninsured exposure.[1]

Governments may directly provide coverage and manage the schemes (i.e., act as a direct insurer) or may support the provision of earthquake insurance by private insurers by providing some form of reinsurance or guarantee. Even where governments have taken a major role in covering the risk, private insurance companies often play an important role in terms of policy distribution and/or loss assessment, or in the risk transfer programme of the schemes (i.e. assuming some of the risk that is covered by the scheme).

The public insurance schemes in France (*Caisse centrale de réassurance* (CCR)), Japan[2] (JER) and Chinese Taipei (TREIF) are structured as reinsurance providers - i.e. earthquake (or broader natural catastrophe) coverage provided by private insurance companies is reinsured by the schemes. In Japan and Chinese Taipei, insurers are required to cede the earthquake insurance that they underwrite to the reinsurance providers (JER and TREIF), although some of the exposure ceded to JER and TREIF is subsequently retroceded back to the insurance sector (i.e. private insurance companies provide reinsurance (retrocession) on the exposure reinsured by JER and TREIF). In France, insurance companies may choose whether they cede their natural catastrophe (including earthquake) risk to CCR and can only cede a maximum of 50% of their risk to CCR (OECD, 2015).

The public insurance schemes in California (United States) (CEA), China, Iceland (Iceland Catastrophe Insurance (ICI)), New Zealand (EQC), Romania (*Pool-ul de Asigurare Împotriva Dezastrelor Naturale* (Insurance Pool against Natural Disasters) (PAID)), Spain (*Consorcio de Compensación de Seguros* (CCS)), Switzerland (canton of Zurich) and Turkey (TCIP) provide direct insurance coverage for earthquake risk. In California, insurers have an option of offering CEA insurance coverage or their own earthquake coverage. In Switzerland, public insurers (cantonal monopoles) have been established in 19 cantons and offer insurance coverage for a number of natural catastrophe perils - although not normally for earthquake damage. The cantonal monopole in Zurich (*Gebäudeversicherung Kanton Zürich - or GVZ*) provides insurance coverage for earthquake risk. In 17 other cantons, voluntary compensation for earthquake damages is available through an earthquake compensation pooling arrangement among the cantonal monopoles (*Schweizerischer Pool für Erdbebendeckung/Pool suisse pour la couverture des dommages sismiques*). The voluntary compensation provided is not insurance coverage and is not legally enforceable by claimants.

The public earthquake (re)insurance schemes mainly provide coverage for residential properties (i.e. earthquake risk faced by households). Some schemes, including CCR, CCS and ICI, offer insurance protection for commercial properties as well. In Spain and France, the coverage is also extended to motor vehicle insurance and to loss of profit (business interruption) under commercial policies. The CCS extraordinary risk coverage extension is also provided for personal damage covered in life and accident policies (including for earthquakes that occur outside of Spain).

The scope of covered perils varies across schemes. In some countries (including those with relatively low earthquake risk, such as France, Spain and Switzerland (Zurich)), the coverage for earthquake risk is part of a broader offering of coverage for a number of natural perils (and also manmade perils, such as terrorism, in the case of Spain). EQC, ICI, JER, and PAID also provide coverage for multiple (although a more limited set of) natural perils - EQC for earthquakes and volcanic eruptions (as well as storm and flood damage to land, not buildings), JER for earthquakes, tsunami and volcanic eruptions, ICI for earthquakes, volcanic eruptions, avalanches, landslides and floods and PAID for earthquakes, floods and landslides. TCIP and TREIF only provide coverage for earthquake risk and secondary perils resulting from an earthquake such as fire and tsunami while CEA only covers damage resulting directly from an earthquake (i.e. ground-shaking).

The public (re)insurance schemes provide coverage for damage to residential (and, in some cases, commercial) buildings, either on a stand-alone basis or as an extension to general property (fire) policies. Most apply an upper limit on the amount of building damages that can be covered by the scheme (CREIP, EQC, JER, TCIP and TREIF) although some (e.g. CEA, CCS, ICI) provide full coverage (net of any deductible or co-insurance) for the amount of the underlying fire insurance policy. The insurance coverage available from the cantonal monopole in Zurich is limited in aggregate to CHF 1 billion per event with claims prorated should the amount of losses exceed that amount. The voluntary compensation provided by other Swiss cantonal monopoles is also limited at CHF 2 billion per event. In the case of PAID, a fixed amount of coverage is provided based on the type of building. Most schemes also provide coverage for contents (CEA, CCR, CCS, EQC and JER) and a few for living expense (CEA and TREIF). Table 4.2 provides an overview of the coverage provided by the schemes.

Earthquake insurance is compulsory (mandatory purchase) for policyholders in Iceland, Romania, the Swiss canton of Zurich and Turkey (within municipal boundaries). In most of these countries, the policies are offered on a stand-alone basis rather than as an extension to fire insurance policies (in Zurich, the coverage is included with other natural catastrophe coverage). The Romanian mandatory scheme imposes monetary penalties of RON 100 to RON 500 (approximately EUR 20-100) in case of failure to purchase an earthquake insurance policy. In Turkey, mandatory purchase is enforced by verifications during land registry transactions and water and electricity subscriptions. In other countries with public (re)insurance schemes (France, New Zealand, Spain and Chinese Taipei), coverage for earthquake insurance is an automatic extension to fire insurance policies. A relatively high-level of fire insurance penetration has meant that the penetration of earthquake insurance is also high in these countries. In Japan and California (United States), coverage for earthquake risk is offered on an optional basis which has resulted in lower overall levels of earthquake insurance coverage than in other countries with public earthquake insurance schemes.

There is also some public backing for earthquake insurance in Albania, Macedonia, and Serbia through the Europa Reinsurance Facility Ltd. (Europa Re**)**. Europa Re is a Swiss-based specialty property catastrophe reinsurance company owned by the countries of South Eastern Europe. Europa Re provides reinsurance for earthquake risk (and other natural perils) to insurance companies in these countries as well as market infrastructure services and technology support.

A number of public (re)insurance schemes charge premiums based on the sum insured without regard to the specific level of earthquake risk, including CCR, CCS, EQC, ICI, and TREIF (although in the case of CCR, deductibles can vary in different municipalities based on factors such as loss experience and the level of investment in risk reduction). In Romania, the premium charged is based on the sum insured (either EUR 20 for EUR

20 000 in coverage or EUR 10 for EUR 10 000 in coverage), although the sum that can be insured depends on the construction attributes of the dwelling. Premiums for coverage provided by CEA, JER and TCIP vary based on the risk zone in which the residential structure is located, as well as various structural parameters. In the case of CEA, the characteristic of the ground on which the structure is built is also taken into account in pricing. JER and TCIP provide discounted premiums for newer buildings while JER also provides discounts for certain earthquake resistant construction features and for multi-year policies. TCIP provides a discount for policy renewals.

The public (re)insurance schemes impose varying levels of co-insurance (Table 4.3). CCR, ICI, EQC, TCIP and CEA impose deductibles ranging from approximately 1% of the insured loss (or replacement value) in New Zealand to up to 25% in some CEA policies. In Spain, deductibles are only applied on commercial policies. Other schemes, including EQC, JER, PAID, TREIF and TCIP, impose a form of co-insurance by limiting the amount that can be insured or by making claims payments based on loss categories which could lead to significant levels of co-insurance (as described below).

Table 4.2. Co-insurance arrangements in public earthquake insurance schemes

Scheme	Description of co-insurance
France (CCR)	Deductibles are applied: Residential: EUR 380 Commercial: 10% of direct damages
Iceland (ICI)	There is a deductible of 5% for each loss as well as minimum deductible amounts: Building: ISK 85 000 Content: ISK 20 000 Public Infrastructure: ISK 850 000
Japan (JER)	No specific deductible although a coverage limit is imposed and claims payments are made based on loss categories.
New Zealand (EQC)	Building: If the loss is NZD 20 000 or less, the deductible is NZD 200. If the loss is larger than NZD 20 000, the deductible is 1%.[1] Content: NZD 200
Romania (PAID)	No specific deductible although a limit is imposed on the amount of coverage available.
Spain (CCS)	Deductible is only applied for commercial policies.
Chinese Taipei (TREIF)	No specific deductible although a coverage limit is imposed and claims payments are made based on loss categories.
Turkey (TCIP)	Deductible is 2% of the sum insured for each loss and a coverage limit is imposed.
California (CEA)	There are different deductible rates based on the replacement cost from 5% to 25% for building and content coverages (the standard CEA policy includes a 15% deductible).There is no deductible for additional living expenses.
Zurich (GVZ)	Deductible is 10% of the sum insured (minimum CHF 50 000). Claims may be prorated for events with an aggregate loss above CHF 1 billion.

1. In 2015, as part of a legislative review of the Earthquake Commission Act, the New Zealand Treasury proposed a standard deductible of NZD 2 000 on all building insurance (New Zealand Treasury, 2015). At the time of writing, this proposal has not been implemented.

Source: Responses to the OECD questionnaire on the financial management of earthquake risk.

Table 4.3. Coverage offered by public earthquake insurance schemes

Scheme	Risks covered	Perils covered	Properties covered	Form of coverage
China (CREIP)[1]	Residential	Earthquake	Building (Urban): USD 7 500 Building (Rural): USD 3 000	
France (CCR)	Residential Commercial Motor vehicle	Natural disasters (as defined by legislation)[2]	Building: No limit (based on underlying policy) Content: No limit (based on underlying policy) Loss of profit: No limit (based on underlying policy)	Reinsurance coverage offered for the natural catastrophe coverage that is automatically included in property insurance (mandatory extension)
Japan (JER)	Residential	Main perils: Earthquake, volcanic eruption and tsunami Secondary perils: Fire, destruction, burial and flooding (resulting from earthquake, volcano or tsunami)	Building: maximum JPY 50 million (30%-50% of fire coverage) Content: maximum JPY 10 million (30%-50% of fire coverage)	Reinsurance coverage provided for optional coverage extension to property insurance (mandatory offer)
Iceland (ICI)	Residential Commercial Public infrastructure	Earthquake, volcanic eruption, avalanche, landslide, flood	Building: No limit (based on coverage limit in fire policy) Content: No limit (based on coverage limit in fire policy)	Stand-alone policy (mandatory purchase)
New Zealand (EQC)	Residential	Main perils: Earthquake, natural landslip, volcanic eruption, hydrothermal activity, tsunami Secondary peril: Fire	Building: maximum NZD 100 000 (+ GST) per event[3] Content: maximum NZD 20 000 (+ GST) per event[3] Land: No specific limit	Extension to property insurance (automatic extension)
Romania (PAID)	Residential Commercial	Earthquake Flood Landslide	Building:[4] (1) EUR 20 000 for type A (2) EUR 10 000 for type B	Stand-alone policy (mandatory purchase)
Spain (CCS)	Residential Commercial Motor vehicle Life and accident Public infrastructure	Natural and man-made extraordinary risks	Building: No limit (based on underlying policy) Content: No limit (based on underlying policy) Loss of profit: No limit (based on underlying policy)	Extension to property insurance (mandatory extension)
Chinese Taipei (TREIF)	Residential	Main peril: Earthquake Secondary perils: (including but not limited to) fire, explosion, landslide, land subsidence, earth movement, rupture, tsunami, tidal wave and flood resulting from earthquake	Building: maximum TWD 1.5 million Living expense: maximum TWD 200 000	Reinsurance coverage provided for coverage extension to property insurance (mandatory extension)
Turkey (TCIP)	Residential	Main peril: Earthquake Secondary perils: Fire, explosion, tsunami, landslide	Building: maximum TRY 170 000	Stand-alone policy (mandatory purchase for dwellings within municipal boundaries)

California (CEA)	Residential	Earthquake	Building: No limit (based on underlying policy) Content: maximum USD 100 000 Living expense: maximum USD 15 000	Stand-alone policy (mandatory offer)[5]
Zurich (GVZ)	Residential Commercial	All-risk (basic coverage for earthquakes above a certain magnitude)	Building: No limit (although per event aggregate maximum of CHF 1 billion)	Basic earthquake coverage is included in building insurance offered by GVZ.
17 Swiss cantons	Residential Commercial	Earthquake	Building: voluntary compensation for earthquake damages through an earthquake compensation pooling arrangement (*Schweizerischer Pool für Erdbebendeckung/Pool suisse pour la couverture des dommages sismiques*)	Voluntary compensation by the pool is automatically included in property insurance policies although is not a legally enforceable insurance coverage

1. In the case of CREIP, only limited information on the specific perils covered and the form of coverage was available.
2. CCR also provides reinsurance to GAREAT in support of the terrorism risk reinsurance coverage that GAREAT provides to its members.
3. In 2015, as part of a legislative review of the Earthquake Commission Act, the New Zealand Treasury proposed an increase to the limit for building coverage to NZD 200 000 (+GST) and the elimination of EQC coverage for contents (New Zealand Treasury, 2015). At the time of writing, these proposals have not been implemented.
4. Type A dwellings: construction with a supporting structure made of reinforced concrete, wood or metal or outside walls made of stone, burnt brick, wood or any other material resulting from heat and/or chemical treatment; Type B dwellings: construction with outside walls made of unburned brick or any other material which has not undergone heat and/or chemical treatment.
5. Insurers in California are legally required to offer earthquake coverage to residential policyholders. The coverage can be that provided by the CEA policy or a policy provided by the insurers themselves.

Source: Responses to the OECD questionnaire on the financial management of earthquake risk. Guy Carpenter (2016)

Some schemes have simplified loss adjustment by basing payouts on categories of loss which can lead to significant levels of co-insurance. In Chinese Taipei, payouts are made only in the case of "total loss" or "constructive total loss".[3] In Japan, JER payouts are based on the level of damage where "total loss" (damage estimated at more than 50% of the cash value of the residence) is paid out at 100% of the sum insured; "large half loss" (damage estimated at 40%-50% of cash value) is paid out at 60% of the sum insured; "small half loss" (damage estimated at 20%-40% of cash value) is paid out at 30% of the sum insured and "partial loss" (damage estimated at 3%-20% of cash value) is paid out at 5% of sum insured (see Box 4.1). A simplified payout structure involving five damage levels paid out at 0%, 50% or 100% of the policy limit has also been established in the CREIP.

Box 4.1. Simplified loss assessment in the context of major earthquakes

The payment of insurance claims requires that affected structures are identified, insurance coverage is confirmed and the damages from the covered event are assessed. While conventional loss assessment approaches based on a detailed loss adjustment will provide more accurate estimates of damages and replacement costs (and ensure payouts that are in accordance with the actual damage incurred), the large volume of claims that follow a major earthquake can create a significant burden on loss adjustment resources and significantly slow the settling of claims. Settling claims based on a categorisation of losses, as implemented in Japan and Chinese Taipei, is a potential solution for accelerating loss assessment and potentially reducing the level of economic disruption in the aftermath of a major event.

Technological developments, particularly improvements in aerial and satellite imagery, as well as the use of new technologies such as drones, can greatly improve the efficiency of this simplified form of loss assessment. For example, aerial photographs were used to determine the amount of claims payments after the Great East Japan Earthquake by providing sufficient evidence that structures located within the coastal inundation zones could be categorised as "total loss" under JER's payout structure. As a result, the vast majority of claims following the Great East Japan Earthquake were settled within three months (compared to years in the case of the Canterbury earthquakes).

One major weakness of this approach, however, is that the use of a simplified payout structure could create significant "basis risk" for policyholders (where payouts vary significantly from the actual level of damage and cost of replacement). For example, a structure with damages equivalent to 19% of the cash value of the residence would only receive a 5% payout from the JER - forcing the homeowner to absorb the remaining (substantial) costs.

Public (re)insurance schemes also differ in terms of the financial support that they receive from governments and their use of reinsurance (or retrocession in the case of public reinsurance schemes). In most cases, the exposure of the scheme is shared between insurance companies and governments, with governments usually taking responsibility for the highest risk layers (i.e. losses from low probability, high impact events). In Japan (as of 1 April 2016), the JER has a total claim payment capacity of JPY 11.3 trillion. Losses up to JPY 115.3 billion are borne by JER; a second layer (losses up to JPY 437.9 billion) is shared among the government (50%), JER (39%) and insurance companies (11%); and a third layer (up to JPY 11.3 trillion) is almost exclusively borne by the government (99.7%). TREIF has TWD 70 billion in total claims payment capacity, including a first layer of up to TWD 3 billion under the responsibility of insurance companies, a second layer (with a limit of TWD 53 billion) that is either transferred to domestic and/or international reinsurance and capital markets or retained by TREIF and a third layer (with a limit of TWD 14 billion) which is covered by the government. In the case of TCIP, the total claims payment capacity is EUR 4 billion of which EUR 250 million is provided by government as excess of loss reinsurance coverage. The CREIP also reportedly benefits from a government backstop (Guy Carpenter, 2016).

A number of the public insurance schemes that provide direct insurance coverage access international reinsurance and capital markets to protect against extreme losses. EQC has access to NZD 4.7 billion of reinsurance to provide for losses in excess of NZD 1.7 billion while ICI has placed two layers of excess reinsurance coverage (a first layer consisting of ISK 15 billion for losses in excess of ISK 10 billion, and a second layer of ISK 15 billion for losses in excess of ISK 25 billion). CEA has USD 4 billion in reinsurance coverage from international markets and has also issued a number of catastrophe bonds since 2011 (most recently, USD 925 million in coverage maturing in May 2020 (Carrier Management, 2017)). TCIP issued a USD 400 million catastrophe bond with a parametric trigger in 2012 (which matured in May 2016). A second parametric catastrophe bond was issued in the third quarter of 2015 providing USD 100 million in coverage (Aon Benfield, 2016). China Re, a public reinsurer that provides reinsurance coverage for the CREIP, issued a USD 50 million catastrophe bond for mainland China earthquake exposure which may include some of the exposure it has accepted from CREIP (China Re P&C, 2016). The public schemes that provide reinsurance coverage, CCR and JER, have not retroceded their exposure in international markets or issued catastrophe bonds (although, as noted, part of JER's exposure is retroceded to domestic insurance companies).

Private insurance coverage for earthquake risk

Private insurance companies are the main (if not sole) providers of earthquake coverage in many countries, including in a number of OECD and non-OECD countries that face a potentially material level of earthquake risk, such as Australia, Austria, Canada, Chile, Colombia, Germany, Greece, Hungary, Italy, Mexico, Papua New Guinea, Peru, the Philippines and Portugal (amongst others). In some countries, private insurers are also the main source of coverage for some of the main secondary perils resulting from earthquakes, such as fire and tsunami (see Box 4.2).

In most countries, private insurers do not include earthquake risk in standard residential or commercial property policies and only make coverage available as an optional extension, endorsement or stand-alone coverage (normally at an additional cost). In many of these countries, including Austria, Germany, Mexico, Philippines and Portugal, optional earthquake coverage is bundled with coverage for other natural catastrophe perils as a specific extension or included only when a comprehensive, or all-risk, policy is purchased. In Canada, the United States and Switzerland, private insurers usually only offer earthquake coverage for residential property as a specific optional add-on or separate stand-alone policy (i.e. not bundled with other natural catastrophe perils).[4] Private insurers in Australia, Belgium and Hungary normally include coverage for earthquake and related perils as a standard inclusion in residential and commercial policies. In a few countries (Albania, Papua New Guinea, Peru and Serbia), some private insurance companies will offer earthquake coverage as a standard inclusion while others will offer coverage as an optional extension.

Box 4.2. Insurance coverage for secondary perils caused by earthquake

In a few countries where earthquake damage is not included in standard property policies, damages that result from secondary perils such as fire or tsunami may nonetheless be covered. For example, in Canada and the United States, fire caused by earthquake is normally covered as part of fire insurance even where specific coverage for earthquake risk has not been acquired. In the United States, standard National Flood Insurance Program policies (FEMA, 2015) include coverage for coastal flooding (i.e. "overflow of inland or tidal waters") without any exclusion flooding that is caused by a tsunami. In Canada, the emerging private residential flood insurance market does not cover tsunami which is also often excluded from earthquake policies. In most European countries where standard coverage excludes earthquakes (e.g. Germany, Italy), fire caused by earthquake is also normally excluded.

Source: Responses to the OECD questionnaire on the financial management of earthquake risk.

In countries with public (re)insurance schemes, private insurance companies might also provide coverage for risks that are not covered by the schemes (e.g. commercial buildings, contents, land) or for amounts in excess of the coverage provided by the schemes (where limited, such as in the case of Japan, New Zealand, Chinese Taipei, Switzerland and Turkey). In Switzerland, where most (17 of 19) cantonal monopoles offer voluntary compensation for earthquake damage (rather than contractually-mandated claims payments), some private insurance companies have developed a form of excess coverage aimed at closing the gap between whatever voluntary compensation is provided and the actual level of damage. In eight other cantons, earthquake insurance is provided by private insurers only, including an insurance company owned by the cantonal monopole insurer of the canton of Bern that offers earthquake insurance in competition with - and subject to same regulatory framework - as private insurers.

Earthquake insurance is not broadly compulsory in any of the countries that rely exclusively on private insurance coverage of earthquake insurance (with the exception of a few specific cases in Costa Rica and Colombia).[5] However, mortgage lenders in a number of countries, including Albania, Chile, Colombia, Costa Rica, Latvia, Mexico, Portugal and Russia, will often require the purchase of earthquake coverage on mortgaged properties.

In most countries, the pricing of earthquake insurance coverage offered by the private insurance sector varies with the level risk, often based on measures of exposure assessed through the use of commercial catastrophe models. The level of granularity in risk-based pricing is usually higher for larger commercial policies than for residential coverage (in a number of countries, premium discounts for more resilient structures are usually only applied in the case of large commercial policies). In some countries (e.g. Colombia, Mexico, the Philippines), regulatory authorities have been instrumental in the development of local catastrophe models for use in pricing which has often been critical for enhancing the market's capacity to provide coverage (see Box 4.3). Similarly, in Albania, Macedonia and Serbia, funding from the World Bank was used to finance the development of an earthquake catastrophe model (AIR Earthquake Model for Southeastern Europe) for application in the underwriting of Europa Re policies.

Box 4.3. Modelling earthquake risk in Mexico

In Mexico, the insurance regulator (Comisión Nacional de Seguros y Fianzas (CNSF)), with the assistance of the Engineering Institute of Universidad Nacional Autónoma de México, developed a methodology and the necessary information technology systems to allow insurers to estimate their seismic exposure for the purposes of solvency, reserve management and pricing. The methodology uses a database of close to 500 earthquake events and their physical parameters. It also usesinformation on common structural characteristics of buildings in Mexico and insurance policy parameters (deductibles, co-insurance, limits) to develop estimates of the pure risk premium to cover potential losses, as well as the Probable Maximum Loss (PML) for each insurer's portfolio.

Source: Mexico's response to the OECD questionnaire on the financial management of earthquake risk.

The level of co-insurance in earthquake coverage provided by private insurers varies across countries, with various levels of deductibles and limits offered to policyholders. A few countries have imposed a standard deductible level or a limit on the maximum level of co-insurance. For example, a 2% deductible must be applied to earthquake insurance policies in the Philippines. In Turkey, private insurers offering commercial or excess residential earthquake coverage cannot set deductibles above 2% or impose co-insurance of more than 20% of the sum insured. In some countries, the level of deductibles can be relatively high. In Canada and the United States, deductibles applied in private insurance policies (as well as in CEA policies) can reach 20% or more. In Washington state, some insurance companies reportedly will not provide coverage with deductibles below 20% (Gilbert, 2016). In Missouri (part of which lies in the New Madrid seismic zone), an estimated 40% of the market requires deductibles of 20% or more, while in Oklahoma (in the New Madrid seismic zone and also exposed to induced earthquakes), a number of insurance companies have eliminated their low deductible offerings. High deductibles, while contributing to lower insurance premiums, could impose a significant burden on policyholders if deductibles are beyond their financial capacity to absorb.

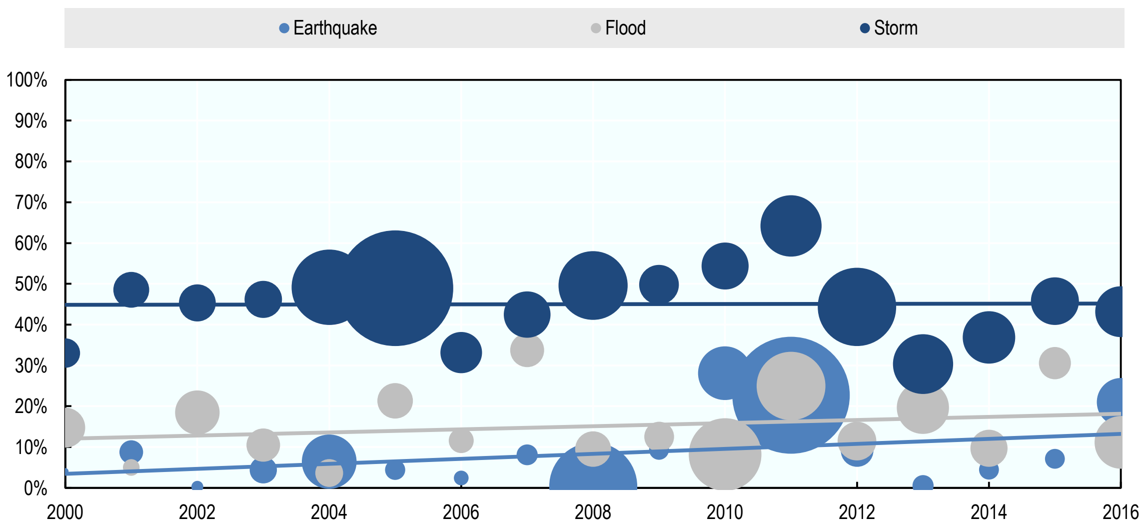
In many countries with more limited property insurance markets, microinsurance schemes have been established to provide some coverage of earthquake losses for vulnerable segments of the population. Many of the microinsurance programmes established have been designed to provide protection for a number of risks including earthquake. For example, Afat Vimo in India provides coverage for property, stock in trade, personal accident, and death from 19 perils including earthquake, fire and flood. The Buhay Buhay Kabuhayan scheme in the Philippines covers losses from personal accident, permanent disability, fire, typhoon, flood, earthquake and lightning (OECD, 2015). In Mexico, a microinsurance product covering earthquake and meteorological risks for low-income families for damages of approximately USD 1 000 to USD 2 000 was being developed in 2015 (Zorrilla, 2015). In Nepal, the Centre for Self-Help Development offers coverage for women at an annual premium of NPR 100, for indemnity coverage up to NPR 6 500 for the repair of a damaged dwelling.

Some microinsurance programmes use parametric triggers as the basis for claims settlement (which can be beneficial in terms of reducing the overall cost of providing coverage). For example, a microinsurance scheme in rural China provides payouts based on the magnitude of the earthquake with a fixed payment of CNY 500 provided for earthquakes with a magnitude of 6.5 or larger, and CNY 1 000 for an earthquake with a magnitude of 8 or larger. Alternatively, the scheme can offer indemnity coverage of up to CNY 16 000 if the property collapses or otherwise becomes uninhabitable (Shah, 2010). Other microinsurance programmes also offer payouts based on a simplified loss assessment process (sometimes for a fixed amount). For example, in the Philippines, a microinsurance scheme provides a set pay-out of PHP 10 000 per unit if the dwelling is damaged or if the policyholder is killed by a natural disaster (OECD, 2015).

Underinsurance of earthquake risk

Earthquake losses (along with flood losses) are the least insured among disaster perils. Since 2000, approximately 85% of reported earthquake losses have been uninsured although there has been some improvement in the level of insurance coverage over time (see Figure 4.1).

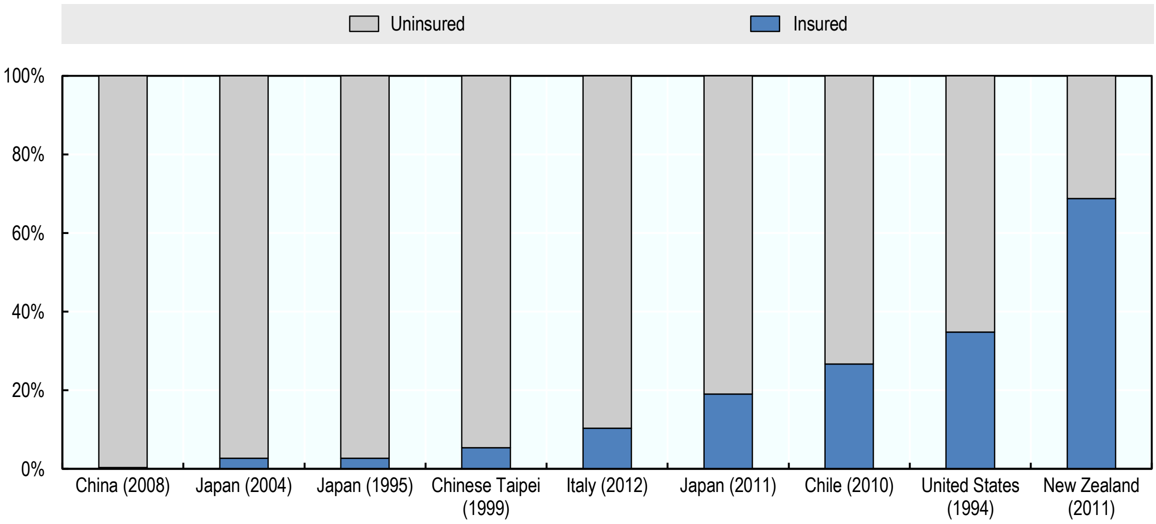
Figure 4.1. Trends in the share of losses that are insured by disaster type



Source: OECD calculations based on insured losses and total losses reported for natural disasters (floods, storms, and earthquakes) by Swiss Re (2017) in constant 2016 USD. The size of the bubbles represents the magnitude of overall losses reported in that year.

The significant underinsurance gap is evident across the costliest earthquakes. Among the costliest earthquake events since 1980, the insured share of losses exceeded 50% for only the Canterbury earthquake sequence in New Zealand and only exceeded 20% of all losses in the case of the Northridge earthquake (United States) and the Maule earthquake (Chile). In the case of two major earthquakes in Japan (the 1995 Hanshin-Awaji earthquake and the 2004 Chuetsu earthquakes) and the Sichuan earthquake in China in 2008, the insured share of losses was less than 5% (see Figure 4.2).

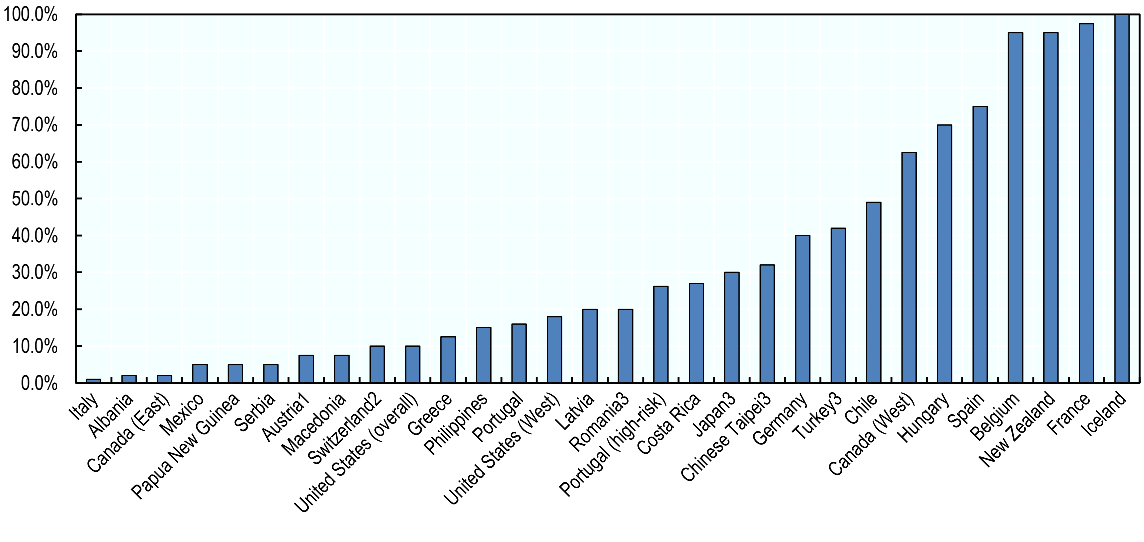
Figure 4.2. Insured and uninsured losses: major earthquake events



Source: OECD calculations based on Munich Re (2016).

The high level of uninsured losses results mostly from underinsurance of residential and public sector assets. In most earthquake-prone countries, the share of households with coverage against earthquake risk is below 50% and less than 10% in some countries. Of the 29 countries and regions for which estimates are available, only about one third have penetration rates above 40% (see Figure 4.3).

Figure 4.3. Estimated share of households with earthquake insurance coverage



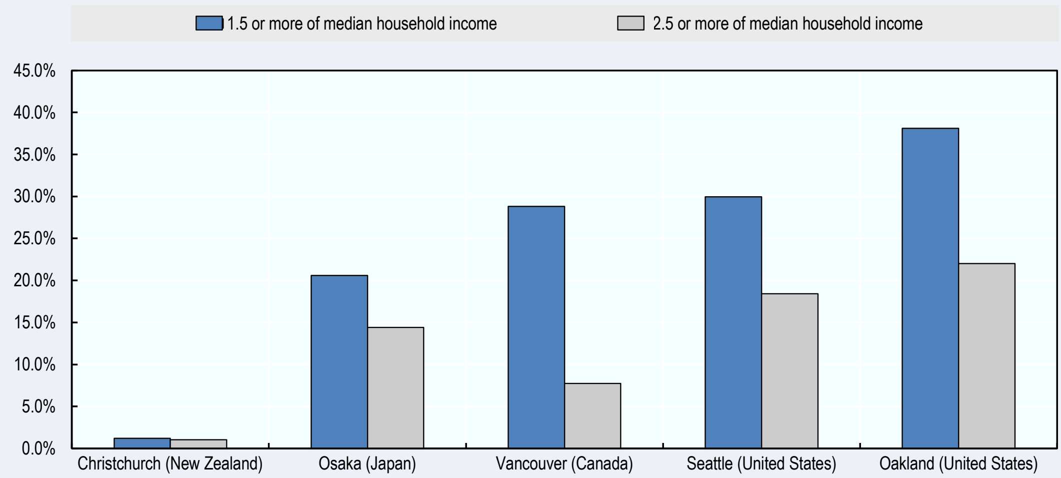
1. The estimate for Austria is based on the sum insured (not the share of households with coverage)
2. The estimate for Switzerland is for optional earthquake coverage, outside of the canton of Zurich where coverage is mandatory.
3. The estimates for Romania, Japan, Chinese Taipei and Turkey only include coverage provided by public earthquake insurance schemes.
Source: OECD questionnaire on the financial management of earthquake risk and sources outlined in Table 4.1.

Box 4.4. The impact of co-insurance - an illustrative example

In a number of countries, private insurers or public earthquake insurance schemes impose high deductibles or low limits on coverage, usually to ensure the affordability of the coverage they provide (by limiting their exposure), or as a result of a specific policy decision to provide only basic first loss coverage through public insurance schemes. Understanding the impact of these practices is critical for assessing the likely distribution of losses once an event occurs and the level of hardship that residential policyholders could potentially face.

As an illustrative example, Figure 4.4 provides rough estimates of the share of households that could be faced with losses equivalent to 1.5 times (and 2.5 times) median household income in different earthquake-prone cities based on prevailing insurance penetration rates and levels of co-insurance (using, for illustrative purposes, the loss distribution experience of the Canterbury earthquakes in 2010-11).

Figure 4.4. Estimates of the share of affected households that would be faced with losses above median income thresholds



Source: According to the Earthquake Commission (reported in Earthquake Commission (2016) and Office of the Auditor General (2013)), the distribution of claims was as follow: 20.6% of claims were for amounts above NZD 100 000; 10.3% were for amounts between NZD 50 000 and NZD 100 000; 32.6% were for amounts between NZD 15 000 and NZD 50 000; and 36.5% were for amounts below NZD 15 000. Using median housing prices across the different cities (NZD 495 000 in Christchurch (ENZ, 2017), JPY 20.6 million in Osaka (Delmendo, 2017); CAD 878 000 in Vancouver (Tencer, 2017); USD 690 300 in Seattle (Zillow, 2017a); USD 687 600 in Oakland (Zillow, 2017b)), the Canterbury claims distribution among affected households was used to estimate an equivalent claims distribution in other cities based on local currencies and housing costs (without adjusting for differences in population). The share of affected households that would face losses above a multiple of median household income (NZD 65 300 in Christchurch (McQuillan, 2016), JPY 6.18 million in Osaka (knoema, n.d.), CAD 79 930 in Vancouver (Statistics Canada, 2017); USD 70 594 in Seattle (US Census Bureau, 2016a) and USD 54 618 in Oakland (US Census Bureau, 2016b)) was then calculated using available estimates of penetration rates (95% in Christchurch, 30% in Osaka, 62.5% in Vancouver; and 18% in Seattle and Oakland), deductibles (2% in Christchurch; 20% in Vancouver and Seattle; and 15% in Oakland) and limits (NZD 100 000 in Christchurch; 40% of sum insured in Osaka or JPY 8.2 million). As the available claims distribution data only includes households that made claims, the share of households that did not face damage is not captured in this example.

Underinsurance may also occur as a result of choices by the policyholder (for example, to reduce the cost of insurance)[6] or based on limitations in the coverage offered by insurance companies and/or public insurance schemes (such as high deductibles or maximum limits on sum-insured). In many countries, high deductibles and/or low limits on earthquake coverage could be an important driver of uninsured losses (see Box 4.4). For example, in Oklahoma, most of the 1 094 claims for earthquake damage since 2010 were not paid because damage levels were below the deductible amount (Brandes 2016). This has led to proposals for insurers to offer earthquake policies with deductibles that are triggered when a cumulative loss amount is reached.

A number of respondents to the OECD questionnaire provided possible reasons for the high-level of underinsurance for earthquake risk, including an expectation that governments would compensate losses (reducing the need for insurance coverage) (Austria, Macedonia, Portugal, Romania, Russia, Serbia, Chinese Taipei, Turkey, United States) and limited awareness of earthquake risk (Canada, Macedonia, Portugal, Romania, Serbia, Switzerland Chinese Taipei). Some countries (Philippines, United States) identified the cost of coverage as a barrier to higher levels of coverage while Colombia identified a lack of availability of earthquake insurance. Chapter 5 will examine some of the factors that limit demand (or willingness-to-pay) for earthquake coverage among consumers as well as some of the challenges that insurers face in providing affordable coverage for earthquake risk.

Notes

1 The schemes under development in Peru and the Philippines have not been included in the discussion of public earthquake insurance schemes as there is limited information available on their structure and the role of government in providing financial support for the schemes. In the Philippines, a model for public-private earthquake pool was developed as part of an Asian Development Bank Technical Assistance project although the model was not approved by the Insurance Commission, Department of Finance and selected insurance and reinsurance companies (Asian Development Bank, 2016).

2 JER is actually a publicly mandated private entity owned by the insurance sector. However, it is included as a public insurance scheme due to an arrangement to share the exposure that JER takes on between government and the private sector.

3 A total loss or constructive total loss can occur as a result of either of the following two situations: (i) the subject matter insured is demolished as informed, ordered or acted by government or civil authorities, (ii) the subject matter insured has been assessed by a qualified adjustor, or by an association of professional architects, structural engineers, civil engineers, or geotechnical engineers, that the insured building has been assessed as inhabitable and in need of demolition and rebuilding; or has been assessed that it could be inhabitable after repairing and the repairing cost equals to or exceeds 50% of the replacement cost at the time when the insured risk occurred.

4 The limited availability of coverage for flood risk in Canada (until recently) and from private insurers in the United States has not allowed for the bundling of natural catastrophe perils as an add-on to residential property policies.

5 In Costa Rica, social interest housing programmes established under the Law of National Financial System for Housing are obligated to acquire fire insurance coverage that includes coverage for earthquake risk. In Colombia, mortgaged properties, common areas in immovable properties, real estate assets of institutions supervised by the Colombia Supervisory Authority (Superintendencia Financiera de Colombia) and securitised real estate assets during the term of trust contract are required to acquire earthquake coverage.

6 Underinsurance could also occur unintentionally, for example where the replacement value of a property is underestimated when obtaining earthquake coverage. The level of underinsurance

due to underestimates of replacement value can be significant. For example, in Australia, a survey of households found that 83% were underinsured for their buildings and contents, including approximately 4% that deliberately underestimated their building value to lower the premium amount (Quantum Market Research, 2013). Similarly, a sample of 630 000 residential and commercial properties in the United States and Canada found that a considerable proportion of the properties were underinsured, notably among rental apartments (14% undervalued) and properties in the wholesale and retail sector (25% undervalued) (Swiss Re, 2015).

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Chapter 5.

Addressing underinsurance of earthquake risk

This chapter outlines the specific challenges to increasing the availability and take-up of earthquake insurance, including the significant potential for severe, correlated losses from earthquake, the challenges in quantifying earthquake exposure and the limited willingness-to-pay for insurance coverage among households and businesses. It provides an overview of measures that can be implemented to reduce the size of expected losses and facilitate the purchase of insurance coverage.

As noted in Chapter 4, a number of factors have led to a significant level of underinsurance for earthquake risk, limiting the contribution that insurance has made to managing the financial impacts of this risk. Similar to other catastrophe risks, the "insurability" of earthquake risk faces a number of challenges that lead insurance companies to charge premiums for earthquake insurance coverage that are beyond the willingness of many policyholders to pay - leading to limited voluntary take-up of earthquake insurance.

The offering of insurance coverage is usually only economically viable when certain "principles of insurability" are present (Swiss Re, 2012; Insurance Europe, 2012), specifically: (i) the risk must be **quantifiable** in terms of its frequency and likely impact (taking into account the physical parameters of the event and the structural characteristics of assets); (ii) a sufficiently large community facing a different (and uncorrelated) level of risk can be established (**mutuality**); and (iii) the risk should be **random**, which implies the time and location of the risk event is unpredictable and the occurrence of the event is not associated with the will of the insureds. These conditions must normally be present for an insurance company to offer coverage for a given risk. Furthermore, to be **economically viable**, the expected loss that the insurance company could face as a result of the coverage provided must be less than the amount of premiums that the insurance company is able to collect (and sufficient to cover administrative costs and returns to investors, where the insurance is provided by private insurance companies). The amount of premiums that insurance companies are able to collect for a given risk depends on the amount that policyholders are willing to pay for that coverage - which may be less than the price at which insurance companies are willing to offer coverage and result in low levels of penetration.

The following sections will provide an overview of various factors that: (i) limit the availability and/or drive up the cost of earthquake insurance coverage; and (ii) reduce the willingness-to-pay of consumers for earthquake insurance. The discussion will also outline efforts in different countries to address these challenges.

Improving the availability of affordable earthquake insurance

Factors affecting the price of earthquake insurance

There are a number of factors that affect the price at which insurance companies are willing to offer earthquake insurance, including the size of expected losses, the difficulty in establishing a pool of uncorrelated risks (i.e. risk diversification) and the level of uncertainty in estimating the potential level of losses:

- ***Size of expected losses***: As noted in Chapter 1, earthquakes are among the most costly of natural perils and have accounted for 6 of the 10 largest natural catastrophe events since 1980 in terms of overall losses. The average earthquake since 1980 (for which economic loss estimates are available) has caused just over 2x more in economic losses than the average climate-related disaster (i.e. USD 9.85 billion vs. USD 4.77 billion) (Swiss Re, 2017). Earthquakes tend to be "tail dependent" due to their potential to trigger secondary perils, such as tsunami and fire (i.e. the low frequency high-impact earthquake "tail" event becomes an even higher-impact tail event as a result of the damages caused by secondary perils) (Kousky and Cooke, 2012). In many cases, such as the Great East Japan Earthquake, the secondary peril (tsunami) caused more losses than the ground shaking. Earthquake risk is also particularly “fat tailed” meaning low probability events have the potential to cause extreme losses. There is also recent evidence that the occurrence of large earthquake events could increase the probability of future events (Cook, 2017). Fat-tailed loss distributions will usually require higher premiums in order to ensure a sufficient pool of capital is available in the event of a large earthquake (Nguyen, 2013). Well-developed reinsurance and alternative reinsurance (i.e. capital markets risk transfer) markets that make coverage available for severe events can, to some extent, reduce these challenges by limiting the aggregate losses that primary insurers face.

- ***Risk diversification:*** Earthquake risk is spatially correlated with the potential to simultaneously impact a large number of buildings and other assets in close proximity. Insurers tend to respond to this type of "accumulation risk" or "correlation risk" by charging higher premiums (OECD, 2016) in order to accumulate sufficient reserves to manage extreme events or by limiting their exposure. For example, the increased demand for earthquake insurance following the 1994 Northridge earthquake in California led many insurers active in the market to restrict the coverage offered (or cease offering property coverage altogether given legal requirements to offer earthquake coverage with property coverage) as a result of their accumulating exposure (eventually leading to the establishment of the California Earthquake Authority). A high-level of correlation risk creates particular challenges for smaller insurance pools with more limited geographical diversification (Schwarze and Wagner, 2007).
- ***Uncertainty in quantification of potential exposures:*** Despite significant improvements in hazard mapping and catastrophe modelling - as well as in the underlying scientific understanding of earthquakes - significant uncertainty remains in terms of the frequency and intensity of earthquake events and therefore the expected losses (see Box 5.1). In some regions, this is exacerbated by increasing frequency and intensity of induced earthquakes which complicates the assessment of potential exposure to earthquake risk (in Oklahoma, for example, this uncertainty has led some insurance companies to increase premium rates for earthquake insurance by up to 300% and others to stop writing earthquake insurance altogether (from 140 in 2014 to 119 in 2016 (Brandes, 2016)). As in the case of other infrequent events, insurers will generally mitigate against high levels of uncertainty about the level of expected losses by charging higher premiums (OECD, 2016).

Measures to reduce expected losses

Ex ante risk reduction measures, such as restrictions on building in high seismic areas, improving and enforcing construction standards for new buildings, strengthening existing buildings (seismic retrofitting) and restricting activities that can trigger induced earthquakes (see Box 5.2), can reduce losses stemming from earthquake events - and can support the insurability of earthquake risk by reducing vulnerability to earthquake damage (and therefore expected losses and the cost of premiums). Risk mitigation measures can have a direct impact on reducing the loss of lives and damage from earthquake events. In the United States, a review of federal mitigation grants over 23 years found an average benefit:cost ratio for investments in earthquake risk reduction is 3:1 (i.e. such investments reap benefits equivalent to 3 times the cost of those investments, on average) (MMC, 2017).

Box 5.1. Earthquake hazard maps and modelling

Earthquake hazard maps and models provide governments, businesses and individuals with critical risk information that can be used for emergency management, relief and rescue operations as well as to assist risk mitigation and risk transfer decisions:

- Earthquake hazard maps describe the probability of exceeding a certain amount of ground shaking in a given a time period (e.g. 50 years). They can be produced for the local, national and/or regional level (e.g. the SHARE seismic hazard map covering Europe) and can be differentiated in terms of probability of occurrence and return interval. These types of maps can have multiple uses. For example, in Turkey, the National Earthquake Hazard map divides the country into five risk zones and is used as the basis for setting the compulsory earthquake insurance premiums for policies offered by the TCIP. In the United States, more than 20 000 cities, counties, and local governments now use hazard maps to create and update building codes (USGS, n.d.).
- Earthquake catastrophe models calculate the probability of loss by combining parameters such as intensity and liquefaction potential and taking into account the geography and vulnerability of assets at risk. Catastrophe models can be designed to provide either probabilistic or deterministic estimates of exposure. Probabilistic models can estimate the range of potential catastrophes and their corresponding losses while deterministic models (scenario-based modelling) take into account a single event and estimate the potential losses (Aon Benfield, 2012). Similar to earthquake hazard maps, catastrophe models are used for a wide variety of purposes, ranging from disaster response planning to risk mitigation and financing. For example, bridge and building construction in California makes use of deterministic models (Wang, 2010). The (re)insurance sector commonly makes use of earthquake catastrophe models developed internally or by commercial providers for managing their exposure. Some governments have also developed earthquake catastrophe models, including HAZUS in the United States and QuakeAus in Australia. In addition, Global Earthquake Modelling (GEM), a non-profit organisation, has developed the first open source model for seismic risk.

While providing a critical contribution to understanding exposure to earthquake risk, the development of accurate models faces a number of challenges:

- Knowledge about seismic hazards is incomplete, which can lead to underestimations of the probability or severity of an earthquake event in a given location. For example, the Canterbury earthquakes occurred on a previously unrecognized fault and produced a stronger ground motion than the hazard map predicted (Reyners, 2011). Similarly, the Haiti earthquake in 2010 occurred on a fault mapped in 2001 as having a low hazard (Stein, Geller and Mian, 2012). Prior to the magnitude 9.0 Tohuku earthquake in 2010, most seismologists believed that Japan could not experience an earthquake beyond a magnitude 8.4 (Schulz, 2015). Induced earthquakes related to energy operations are a new concern for modelling earthquake risk. The primary challenge is constructing realistic seismicity and ground motion models for induced earthquakes given the lack of data on - and thus uncertainty in - the ground motion and potential magnitude of these types of earthquakes (Pontbriand, 2016).
- The modelling of earthquake risk is complicated by the potential for earthquakes to cause secondary loss agents such as after-shocks, tsunami and liquefaction (which as noted, can increase the aggregate level of losses significantly, as occurred in Japan (2011) and New Zealand (2010/2011)). These secondary loss agents must also be mapped and/or modelled which creates additional uncertainty about loss estimates. For example, the tsunami inundation area in Ofunato and Sendai cities after the Tohoku earthquake was underestimated on the hazard map (Ranghieri and Ishiwatari, 2014). A particular

challenge is estimating the impact of after-shocks on structures damaged by the initial event. The model coverage of these secondary loss agents - while improving - is not universal.

- In many countries, there is insufficient information available on exposed structures and their construction characteristics. The relative infrequency of earthquake events has also limited the amount of event information available to analyse the impact of earthquakes on different types of building structures.

However, despite the potential benefits of risk mitigation measures, there is general under-investment by governments in disaster prevention and risk reduction. Most countries allocate significantly more funds to disaster response than risk reduction. The US federal government spent an average of over USD 3 billion on disaster response annually between 1985 and 2004 compared to USD 195 million on disaster prevention during the same period (Healy and Malhotra, 2009). In the past two decades, approximately 87% of the estimated USD 107 billion provided as development assistance for disaster-related programmes was devoted to post-disaster response and reconstruction, and only 13% was devoted to risk reduction and other *ex ante* risk management measures (Keating, A. et al., 2014).

Voluntary implementation of risk reduction measures by individuals is also limited due to many of the same factors that result in low take-up of insurance (low awareness, affordability concerns and expectation of government financial assistance - as discussed in the next section). For example, in the United States, only an estimated 10% of earthquake and flood prone households have adopted mitigation measures (Kunreuther and Michel-Kerjan, 2012). The following sections provide an overview of *ex ante* risk reduction measures that can reduce earthquake risk and improve insurability along with challenges to their implementation and initiatives to encourage risk reduction.

Box 5.2. Reducing the potential for induced earthquakes

As induced earthquakes are caused by human activities, the risk of induced earthquakes can be reduced either by ceasing the activity that is causing the earthquakes or taking steps to modify the activity in ways that reduce the potential to trigger an earthquake. In Oklahoma (United States), regulators have imposed a limit on the volume of wastewater that can be disposed as a by-product of extractive activities (Traywick, 2017) and also require operators to undertake real-time seismic readings and reduce (or temporarily shut down) their fracking operations in response to seismic activity (Insurance Journal, 2018b). These measures may have had some success as the frequency of induced earthquakes declined significantly from 2015 to 2016 (Insurance Journal, 2018d; Traywick, 2017). Recent studies have identified other potential ways to reduce earthquake risk related to fracking operations, including establishing a minimum distance between geological faults and fluid injection points (Newcastle University, 2018) and reducing the depth of injection wells to levels above basement rocks (Insurance Journal, 2018a).

Land use restrictions

Subsurface conditions and proximity to fault lines can impact the magnitude of earthquake losses. The application of land use restrictions in areas close to fault lines or with less solid underlying terrain can therefore make an important contribution to reducing losses. In some countries, there have been initiatives to limit construction in high seismic areas. In the United States, for example, the *Alquist-Priolo Act of 1972* is designed to prevent development along active fault lines in California by requiring a seismic risk evaluation of sites by an engineering geologist prior to development. The Philippines and Costa Rica have also applied some restrictions on construction in seismic areas and/or near active fault lines. In Costa Rica, urban planning takes into consideration earthquake risk for new construction. Land-use decisions can also reduce the potential for losses from secondary perils, for example by restricting the development of low-lying coastal zones at risk of tsunami or ensuring sufficient buffers between structures (or neighbourhoods) to mitigate the spread of fire.

In many countries, decisions on land-use planning are made at local levels which often face pressure to allow the development of land subject to earthquake (or secondary peril) risk, particularly in densely populated countries or regions with limited land available for development. Local governments may also be incentivised to allow for the development of land - which generally brings benefits in terms of local tax revenue and potentially few costs if national governments contribute to a significant share of the cost of rebuilding after an earthquake event. Restrictions on access to insurance in high-risk zones can support the implementation of land use restrictions in risky areas. By contrast, the broad availability of affordable insurance coverage in communities facing significant earthquake risk could encourage development in those areas and increase the number of properties at risk.

The effectiveness of land-use policies in reducing risks will also be limited where urban areas are already located in seismic areas and vulnerable to the impact of earthquakes or secondary perils. In this case, governments may consider the relocation of communities from high seismic areas to relatively safer regions. Public financial support for the purchase of high-risk properties could remove an important barrier to relocation. For example, after the Canterbury earthquake sequence, the New Zealand government identified a red-zone area (the highest seismic region) and offered to buyout buildings in this area. Over 95% of the eligible property owners participated in the programme resulting in the government purchasing 7 300 properties in the red zone (Mitchell, 2015). While the feasibility of relocation programmes will likely be highest after an earthquake event (Coburn and Spence, 2002), some countries have established programmes to encourage relocation before an event occurs. For example, in 2012, Turkey launched an urban transformation project aimed at identifying and demolishing unsafe buildings in risky zones. Under this plan, building-owners can voluntarily demolish their buildings in return for compensation with the potential for government to require that buildings it deems unsafe be evacuated and demolished (with affected homeowners receiving new apartments in the same area or loans to buy housing in other areas).

Building codes

Building standards can directly impact the capacity of buildings to withstand earthquake events thereby preventing loss of lives and reducing damages. Buildings that are designed to allow for vertical and lateral movement, including by decoupling the building's base from its upper levels (i.e. base isolation), and that make use of more resilient construction materials such as reinforced concrete and steel, are generally better able to withstand the impacts of ground-shaking (Giles, 2017). Many recent earthquakes have demonstrated that new buildings with higher construction standards perform better than older buildings not designed to take into account seismic risks. For example, buildings constructed in Japan after 1981, when the current building code was implemented, incurred less damage from ground shaking during the Great East Japan Earthquake (Ranghieri and Ishiwatari, 2014). Similarly, in Chinese Taipei, recent earthquakes have mostly led to the collapse of buildings constructed before the implementation of stricter building codes in 1999 (Hetherington, 2018). By contrast, the weak building quality in Haiti was reported to be the main cause of the significant death toll and destruction of buildings that occurred during the earthquake in 2010. Similarly, a survey of 1 000 building structures in Kathmandu valley (Nepal) found that many buildings were constructed by homeowners without the application of any seismic design standards, resulting in most buildings in the affected region facing at least slight damage as a result of the 2015 earthquake (UNISDR, 2015).

As earthquake engineering has progressed, increasing focus is being placed in minimising damage, in addition to the traditional focus on protecting lives from building collapse (Balance, 2018). Building standards increasingly incorporate some form of performance-based construction standards for seismic risk that apply objectives for building performance based on its function and taking into account the relative level of seismic risk for the given location. In the European Union, for example, Eurocode 8 provides design standards for earthquake resistance that aim to protect human lives, limit damage levels and ensure that important structures (e.g. hospitals, bridges, etc.) are operational after earthquake events. In the United States, the National Earthquake Hazards Reduction Program (NEHRP) Recommended Seismic Provisions for New Buildings and Other Structures (FEMA, 2015) aims to avoid serious injury and life loss due to structural collapse, failure of non-structural components or systems, release of hazardous materials and loss of function in critical facilities, preserve means of egress, and reduce structural and non-structural repair costs where practicable. To support performance-based seismic engineering, comprehensive technical guidance and tools for assessing building seismic performances against losses and expenses have also been developed (FEMA, 2016a). In Mexico City, the Secretariat of Works and Services' building code contains minimum design requirements against earthquakes and norms aimed at ensuring no loss of life or major structural failure based on a maximum probable earthquake scenario. In California, a proposed law would extend this kind of mandate to include all engineered buildings, requiring codes strong enough to ensure that buildings do not just avoid collapse but also remain functional after an event (Los Angeles Times, 2018).

Experience from actual events has also been the basis of building code revisions. In Turkey, the seismic design code mandate was renewed in 2007 based on experience from the 1999 Marmara earthquake. In New Zealand, a *Building (Earthquake-prone Buildings) Amendment Act of 2016* incorporated experience from the 2010/2011 Canterbury earthquakes while the partial collapse of a modern building in Wellington following the 2017 Kaikoura earthquake led to calls for a further review (Perry, 2017). In the Philippines, the national structural code is regularly updated by the Department of Public Works and Highways. In Spain, building codes are being reviewed as a result of the Lorca earthquake in 2011, including with the use of insights based on CCS claim experience (Álvarez, Díaz-Pavón and Rodríguez, 2014).

Similar to land-use planning, building codes are often established - and almost always enforced - at local levels. Some countries (e.g. Philippines) noted that gaps in local enforcement limited the application of national design standards as structures may be constructed without the necessary permits or seismic engineering. In Canada, the national building code is voluntary and is adopted on an ad-hoc basis by provinces and territories. In New Zealand, the application of national standards at the local level allows for consideration of local seismic, economic and social conditions which allows for some divergence in the standards applied in different parts of the country. The implementation of standards in construction might also lead to lower levels of earthquake resilience than planned as a result of execution deficiencies or underperformance of design in the face of an actual event. For example, a structural analysis of a sample of buildings in Mexico City constructed after the implementation of the 2004 building code found that 36% and 71%, respectively, did not achieve service (i.e. displacement and vibration) and ultimate (i.e. resistance) limit prescribed in the building code (Reinoso, James and Torres, 2016). Gaps in building standard enforcement have been found to lead to greater levels of damage after past events. The California Seismic Safety Commission's investigation of damage from the Northridge earthquake in southern California, for example, found that there would have been far less damage if building codes had been rigorously enforced (May et al., 1999). Lack of enforcement of building codes was also identified as a major contributor to losses after the Marmara earthquake in Turkey (Allen, 2007). Insurers and other financial institutions could encourage greater enforcement of building codes by requiring an inspection of the property against code requirements before issuing a mortgage or providing insurance coverage. For example, the Disaster Insurance Law in Turkey allows TCIP to refuse offering earthquake insurance coverage for dwellings that do not meet the required construction quality.

Seismic retrofitting

Land use restrictions and building codes are mainly applied to new construction. However, in many long-established cities, the renewal of the building stock (i.e. replacement of old structures with new buildings) is slow, thereby limiting the impact of these risk reduction measures. In Switzerland, for example, 53% of residential buildings were built before the first earthquake design requirements came into force in 1970 - as a result, an earthquake with a magnitude of 6.4 to 6.8 in Basel could lead to damages to an estimated 275 000 buildings (Swiss Re, 2016). Many of the buildings destroyed in towns devastated by the August 2016 earthquake in Italy were built more than 100 years ago using traditional unreinforced masonry construction with thick walls made of large rocks and rubble held together with weak mortar (Krezel, 2016).

For these legacy structures, mitigation of earthquake risk can only be achieved through seismic retrofitting. A number of countries and regions have invested in surveying their building stock to identify structures at risk of failure. In New Zealand, commercial and public buildings constructed before 1976 that do not meet 33% of the New Building Standard requirements are identified as earthquake prone buildings and owners must strengthen or demolish them within a set period of time (McRae et al., 2017). In the Tokyo Metropolitan Region (Japan), structures are assessed every five years for performance related to both ground-shaking and fire spread with the objective of achieving 90% quake-proof structures by 2019 and 100% by 2025 (Osumi, 2018). In Chinese Taipei, the February 2018 earthquake led to an initiative to inspect 34 000 structures and establish requirements for owners to ensure the safety of those structures (Jennings, 2018). In California (United States), legislation has been proposed to require the identification and cataloguing of seismically vulnerable buildings (Sahabi, Reis and Khorram, 2018). In the United States, the Federal Emergency Management

Agency's State Earthquake Assistance Program has provided support for developing an inventory of seismic vulnerable buildings in at-risk communities (NEHRP, 2017), often carried out using a Rapid Visual Screening (RVS) methodology (FEMA, 2016b) and targeted to critical public building stocks such as school buildings. For example, in the state of Utah (United States), an initial pilot project evaluated 128 school buildings and found 60% to have collapse risk (USSC, 2011) leading to state legislation aimed at funding a state-wide seismic safety screening of school buildings.

Seismic retrofitting approaches can include both contributing to a building's structural elements (e.g., foundation, load-bearing walls, beams, columns, floor system, and roof system along with the connections between these elements) as well as its non-structural elements (e.g., bracing exterior elements, anchoring interior elements, protecting electrical, mechanical and plumbing systems and securing building contents) (FEMA, 2004). There is a limit in terms of how effective seismic retrofitting can be in terms of protecting older structures against earthquakes, especially the unreinforced masonry structures common in many historical cities and villages in Europe. However, experience from recent earthquakes in central Italy has provided some examples of retrofitting measures that could improve overall performance (e.g. mortar injections, bi-directional seismic ties) (Lloyd, 2017). In Mexico, significant investments in seismic retrofitting (and building code improvements) likely contributed to fewer casualties and less damage from the earthquake in September 2017 relative to 1985 (see Box 5.3).

Box 5.3. The impact of two earthquakes in Mexico City

On 19 September 1985, Mexico City was affected by a magnitude 8.1 earthquake that led to approximately 10 000 deaths, the collapse of hundreds of buildings and economic losses of approximately USD 9.2 billion (in current dollars) (Ahmed, Franco and Fountain, 2017; Aon Benfield, 2017). In the aftermath of this event, Mexico invested significantly in improving building codes and strengthening the seismic resilience of critical infrastructure and tall buildings which were particularly affected by the 1985 earthquake (with some of the tallest structures now reportedly able to withstand a magnitude 8.0 earthquake) (Godby, 2017; Leoni, 2017).

Thirty-two years later to the day, Mexico City was affected by a 7.1 magnitude earthquake - although with very different consequences. The level of casualties and damages - while still significant - were a fraction of the levels of 1985 (as noted above, approximately 330 people were killed and 44 buildings collapsed). Critical infrastructure, including electricity, telecommunications and the airport, remained functional with only limited disruptions to the metro system and to flights (Barrios Gomez, 2017).

There were important differences between the two earthquakes. The 1985 earthquake was much stronger, releasing approximately 30 times more energy than the earthquake in 2017. The epicenter of the 1985 earthquake was further away, which would normally reduce the impact on Mexico City, although there is some evidence that the distance led to more damage among taller buildings housing larger numbers of people (the buildings that collapsed in 2017 were mostly multi-story buildings although much shorter than the high-rises that collapsed in 1985) (Ahmed, Franco and Fountain, 2017). Gaps in building code enforcement have also become apparent in the aftermath of the 2017 earthquake, most notably in the tragic case of a relatively newly constructed school that collapsed while an older adjacent school structure remained standing (Solomon and Eschenbacher, 2017).

One of the main impediments to broader seismic retrofitting is cost - despite some research suggesting a benefit:cost ratio of 7:1 for retrofitting "soft-story" structures (i.e. multi-story structures with large unobstructed openings, such as commercial spaces or windows, that reduce the structure's earthquake resilience) (Sahabi, Reis and Khorram, 2018). For most buildings, the cost of retrofitting is thought to range between 5% and 40% of the cost of constructing a new building. In addition, buildings usually need to be vacated during the retrofit causing additional disruption and cost. A survey in New Zealand, for example, found that 90% of the interviewees thought that the cost of seismic retrofitting was excessive (Egbelakin, Wilkinson and Ingham, 2014) despite the potential risk reduction benefits. Less-intrusive retrofitting of non-structural elements may be more cost-effective given the tendency of these elements to account for a large share of earthquake damages (non-structural elements, such as mechanical, electrical, plumbing, and architectural elements, can account for 70%-85% of the original construction cost of a new building (FEMA, 2012)). However, most examinations of households' willingness to invest in risk reduction have found that residents in hazard-prone areas are unlikely to undertake loss-prevention measures voluntarily. A 1974 survey of more than 1 000 California homeowners in earthquake-prone areas revealed that only 12% of respondents had adopted protective measures (Kunreuther et al., 1978). Fifteen years later in 1989, there was little change despite the increased public awareness of the earthquake hazard - among 3 500 homeowners in four California counties at risk from earthquakes, only 5% to 9% of the respondents reported adopting any loss reduction measures (Kunreuther, 2008). Similarly, a survey of 254 homeowners in Istanbul after Turkey’s 1999 earthquake found that only a fifth of respondents had taken some preventive action: 13% inside the home and 9% with the aim of strengthening the building (Fisek et al., 2002). More recently, a survey of residents in Nagoya (Japan) and the San Francisco Bay area (United States) found that only 16.7% and 26.2% of residents, respectively, had undertaken measures to improve the earthquake resistance of their homes, even though there was broad awareness of the potential for a life-threatening earthquake and a significant level of experience of past earthquake damage (particularly in San Francisco where 32.2% of respondents had faced earthquake damages in the past) (Johnson and Nakayachi, 2017).

In addition to the well-known reasons behind households’ reluctance to invest in risk reduction (low risk awareness, expectation of government assistance, etc.), the significant cost of seismic retrofitting exacerbates this challenge in the case of earthquake risk. Household decision-makers tend to exhibit myopic behaviour where they focus solely on the potential benefits of an investment over a short-period of time, such as 2-3 years, and therefore under weigh the benefits of mitigation investments over the longer-term. If a homeowner is planning to move in the next several years and believes that the investment in mitigation measures will not be captured through an increase in the valuation of their home, then it would not be considered worthwhile to incur the cost of the disaster-reduction measure (Kunreuther and Michel-Kerjan, 2013). A study of mitigation decisions found that only home ownership and length of residence were relevant criteria in decisions to implement mitigation measures (Spittal et al., 2008). In multi-residential structures, a 'tragedy of the commons' scenario may exist as individual residents will have very little incentive (or opportunity) to invest in risk reduction unless all other residents also contribute to such investments.

Insurance premiums and deductibles that reflect risk - and provide discounts for risk mitigation - can provide incentives for risk reduction. Through risk-based insurance premiums, insurers communicate the risk level of properties to policyholders which could encourage mitigation by property owners (particularly if premium discounts are offered for risk reduction measures). For example, starting from 2016, CEA offers up to a 20% discount in premium for retrofitted older houses (built before 1979)[1] which should counteract some of the cost of such measures (CEA and the state government also provide up to USD 3 000 in financial support for retrofitting expenses - see Box 5.4). TCIP and JER also provide discounted premiums for building with higher levels of earthquake resistance (usually newer buildings although potentially also applicable to buildings that have been retrofitted). In many countries, private insurers will also provide premium discounts for buildings that have been strengthened or designed to a higher standard of earthquake resistance although such discounts are often only applied in the case of larger (commercial) policies.

Incentives such as tax exemptions and the availability of long-term loans or other financial support can also be used to encourage households and businesses to implement risk reduction measures. In New Zealand, the Wellington City Council offers a tax rate reduction for buildings that become unoccupied during seismic retrofitting and subsidies to support retrofitting costs (McRae et al., 2017). In Russia, the Federal Target Program, which was approved to operate until 2018, provides funding to regional governments for seismic strengthening of existing facilities and construction of new earthquake resistant buildings, including for residential structures. In California, the city of Berkeley provides a reimbursement of up to one-third of a 1.5% tax levied on property transfers for seismic upgrades during the sale of the property (including foundation repairs or replacement, wall bracing in basements, shear wall installation, water heater anchoring, and securing of chimneys (Kunreuther and Michel-Kerjan, 2013)).

Box 5.4. Earthquake Brace and Bolt Programme in California

The California Earthquake Authority (CEA) and the State of California created the "Earthquake Brace and Bolt" programme to provide homeowners with a financial incentive to retrofit their homes to protect against earthquake damage. The programme offers up to USD 3 000 to qualifying homeowners whose homes meet a specified criteria (i.e. the home has to have been constructed before 1979, built on a level or low-slope site, constructed with a four-foot or less cripple wall under the first floor, and have a raised foundation). Households may opt to either hire a contractor or do the work themselves. A typical retrofit performed by a contractor may cost between USD 3 000 and USD 7 000 depending on the location and size of the home, contractor fees, and the amount of materials and work involved (California Earthquake Authority and California Governor's Office of Emergency Services, n.d.; California Earthquake Authority, 2016). If the homeowner opts to do the work themselves, costs can be less than USD 3 000.

To increase the attractiveness of the programme, a recent bill has been introduced in the US Congress to exempt any mitigation assistance received from federal taxation (Earthquake Mitigation Incentive and Tax Parity Act of 2017) (Insurance Journal, 2017). Even without the tax exemption, demand for the assistance has been substantial as 7 500 requests were reportedly received for the period ending in February 2018 for the 2 000 grants available (Insurance Journal, 2018c).

Many governments also have funding programmes to strengthen the earthquake resistance of public buildings and infrastructure, such as schools and hospitals (e.g. Costa Rica, Switzerland, Turkey). In the United States, FEMA's Hazard Mitigation Grant

Program and Pre-Disaster Mitigation programmes support earthquake mitigation projects targeted at public assets at all levels of government, such as community buildings, schools, municipal water systems, power transformers, fire stations, etc. Over the last 30 years, FEMA has committed 15 billion USD in Hazard Mitigation Assistance grants.

Measures to reduce uncertainty about exposure

As noted above, the significant complexity involved in quantifying exposure to earthquake risk will generally lead insurance companies to charge higher premiums to account for the potential that their pricing underestimates their actual exposure. Developments in the accuracy and coverage of catastrophe modelling, and the underlying scientific understanding of earthquake risks (including the identification of new active faults and evidence of major historical earthquake events), can contribute to reducing the level of uncertainty about exposure estimates and the characteristics of very low frequency extreme events that have only occurred in the distant past.

The coverage of commercial catastrophe modelling has increased significantly in recent years. The major commercial modelling firms have released models covering North America, the Caribbean, Europe, Turkey, Australia, New Zealand, Japan, China, India, Chinese Taipei and a number of countries in Southeast Asia (Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam) and South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru and Venezuela). In 2017, a model covering earthquake risk in 11 Middle Eastern countries (Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen) was developed (Lloyd's, 2017). In some cases (e.g. Colombia and Peru), model development has responded directly to regulatory requirements for their use in calibrating capital and reserve requirements. Secondary perils, including fire following earthquake, liquefaction, tsunami and landslides, have been included in a number of the commercial models, including the full set of secondary perils in North America and Japan; tsunami in Chile, Colombia, Ecuador and Peru; liquefaction in Australia, India, Singapore, Thailand and Viet Nam; and both liquefaction and tsunami in Indonesia, Philippines and Chinese Taipei. There have also been a number of recent improvements in the modelling approach, such as more detailed analysis of the ignition potential and emergency response capacity for fire following earthquake (Krezel, 2017) and the use of remote sensing to monitor stress accumulation in active fault lines (O'Donnell, 2017).

Public sector agencies are also improving scientific understanding and data availability in areas critical for improving the quantification of earthquake risk. The United States Geological Survey has integrated risk from induced earthquakes in recent updates of its seismic hazard maps (USGS, 2017) while researchers at Stanford University have developed an analytical tool to identify fault lines where wastewater injection could trigger earthquakes (Than, 2017). This has allowed commercial modelling firms to integrate induced earthquake risk into new (or forthcoming) model releases for the United States (O'Donnell, 2017; RMS, 2017). In Europe, the Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe has launched a project aimed at improving the availability of building inventories across Europe with detailed typologies of construction types relevant for assessing the level of seismic risk (Trigka, 2017).

Measures to manage expected and peak losses

Earthquake reserves and solvency requirements

Similar to other insurance business lines, expected losses due to exposure to earthquake risk are managed through technical provisions/reserves and capital requirements aimed at absorbing losses beyond the reserves set aside. Reserves and capital allow insurance companies to set aside funds to absorb losses from severe events that usually benefit from more favourable tax treatment.[2] Regulatory measures and tax requirements should therefore be established with the aim of balancing the need for companies to set aside sufficient funds to cover extreme events while ensuring that profits are subject to taxation at appropriate levels (i.e. that companies do not allocate excessive profits to reserves in order to reduce their tax burden). How regulators and tax authorities balance these objectives has an impact on the cost of funds backing earthquake exposure and therefore the cost of supplying insurance coverage for earthquake risk (low allowances for reserve accumulation or high capital requirements can both affect the willingness of insurance companies to provide coverage for earthquake risk).

A few earthquake-prone countries, including Albania, Canada, Chile, Colombia, Mexico, Philippines, Portugal, Russia, Serbia and Turkey allow for (or require) the establishment of specific reserves or provisions for seismic risk. Costa Rica is also developing a specific provision that will apply to earthquake and volcano risk. In terms of capital requirements, most countries use some form of value-at-risk (VAR) measure to calculate the amount of capital that insurance companies must hold to cover potential losses on the insurance coverage that they have provided. Among EU countries, the VAR threshold is usually established at 99.5% (i.e. 1-in-200 year return period), consistent with Solvency II requirements. In Canada, the level is set at a 1-in-500 year return period (i.e. 99.8%) and in New Zealand, it is set based on a 1-in-1 000 year return period (i.e. 99.9%). Other countries use other types of risk measures to establish capital requirements, including requirements based on probable maximum loss (usually based on a modelled estimate) and the amount of exposure retained by the insurance company. In Mexico, the Comisión Nacional de Seguros y Fianzas (CNSF) has developed specific software to help companies calculate required reserves and capital levels based on estimates of probable maximum loss.

Reinsurance and capital markets risk transfer

In addition to establishing reserves and holding capital to absorb losses from large earthquakes, insurance companies can transfer a share of their exposure to international reinsurance and capital markets or to public reinsurance schemes where such schemes have been established (France, Japan, Chinese Taipei). Reinsurance, retrocession and capital market risk transfer instruments can provide additional layers of risk absorption capacity and potentially reduce the risk of extreme losses, therefore contributing to overall market capacity and insurance affordability. The global nature of these markets also allows for some portion of the losses from an earthquake event to be absorbed by international markets (and investors) thereby diversifying the burden away from the affected country.

In many countries, a significant portion of exposure to earthquake is transferred to international reinsurance markets. In Chile, Costa Rica, New Zealand (private sector coverage), Papua New Guinea, Russia and Serbia, more than 90% of earthquake exposure is transferred to international markets. In Albania, Canada, Portugal and the Philippines, over 60% of exposure is transferred to international markets. As noted in Chapter 3, the public (re)insurance schemes in Iceland, New Zealand, Turkey and the United States (California) also transfer significant amounts of earthquake exposure to international reinsurance and capital markets.

Capital markets are providing an increasing amount of coverage for earthquake risk. Risk transfer to capital markets is most commonly done through the issuance of catastrophe bonds although other risk transfer mechanisms such as sidecars/quota shares, industry loss warranties and collateralised reinsurance/retrocession are also used.[3] Outstanding catastrophe bond capital reached more than USD 31 billion in the first quarter of 2018 (Artemis, 2018a). Earthquake and storm exposure are the most common natural disaster perils transferred to capital markets. In terms of earthquakes, most capital market risk transfer is for earthquake exposure in the United States (approximately USD 3.5 billion in outstanding capital as of March 2018) and Japan (approximately USD 2.7 billion in outstanding capital), although earthquake exposures in Latin America, Europe, Turkey and China have also been transferred to capital markets (Artemis, 2018b).

The relative cost of risk transfer to reinsurance and capital markets is impacted by the extent to which that risk transfer benefits from a reduction in capital requirements. Most countries provide a capital credit for the transfer of earthquake exposure to reinsurance and capital markets although many take into account the credit risk of reinsurers to which the risk has been transferred (providing reduced credit for transfers to less creditworthy reinsurers). Some countries treat capital market risk transfer differently than transfer to reinsurance markets, for example by considering the level of basis risk (Germany), by requiring specific approval for capital reductions related to capital markets risk transfer (Canada) or by not allowing any capital credit for exposure transferred to capital markets (New Zealand).

Addressing limited demand for earthquake insurance

Factors affecting the willingness-to-pay for earthquake insurance

There are a number of factors that affect the willingness of households and businesses to pay for earthquake insurance coverage including the level of awareness of earthquake risk and what financial protection options are available as well as the availability of government compensation for earthquake losses:

- ***Level of awareness of earthquake risk***: In general, households and businesses tend to underestimate their exposure to low-probability disaster risks, which reduces their willingness to pay for insurance coverage (OECD, 2016). Major earthquake events occur infrequently, leading many of those exposed to earthquake risk to discount the likelihood that they will be impacted by an earthquake in their lifetime.
- ***Misunderstanding about insurance coverage for earthquake risk***: Households and businesses with property insurance coverage may be unaware of any exclusions in coverage for earthquakes or other natural disasters and assume that their exiting property policies cover such damage. In Australia, for example, one survey found that 45% of respondents were unaware whether their insurance policy provided coverage for earthquake damages (Insurance Council of Australia, 2013).

- ***Expectation of government assistance or compensation***: An assumption that governments will provide compensation or financial assistance to households and businesses impacted by an earthquake could negatively impact the willingness-to-pay for earthquake insurance. Government financial support could be perceived as a "free" substitute to the purchase of insurance coverage. This has the potential to become self-reinforcing as low levels of insurance coverage will normally increase the pressure on governments to provide financial assistance, which - if provided - could lower the willingness-to-pay for insurance coverage in the future (Kunreuther, 1996).

Measures to address the limited to demand for earthquake insurance

To address the factors that limit the willingness-to-pay - and ultimately the demand - for earthquake insurance coverage, many governments have invested in enhancing public awareness of earthquake risk and the financial protection options available. Some countries also provide premium subsidies as a means to incentivise the purchase of insurance and overcome some of the challenges to affordability. In many countries, various forms of compulsory purchase have been implemented to ensure that households (and sometimes businesses) are sufficiently covered. The following sections provide an overview of some of the approaches that have been taken to enhancing demand for earthquake insurance.

Enhancing awareness of earthquake risk

As noted, there is a general tendency among households and businesses to underestimate their level of exposure to earthquake risk. Most countries implement various approaches to improving the public's understanding of earthquake risk, for example, by making information on earthquake risk publicly available or organising community-level campaigns aimed at improving awareness and understanding of earthquake risk. In most cases, the primary rationale for awareness efforts is to improve emergency preparedness - although a few countries (e.g. Japan, Philippines, Portugal, Spain, Switzerland, Chinese Taipei and United States) suggested that increasing the insurability of earthquake risk (by increasing awareness of the need for financial protection) was a moderate or important rationale for awareness raising activities.

Many countries publish specific hazard maps in order to make information on risk available to households and businesses although the level of awareness of the existence of these maps may be limited. For example, almost all municipalities in Japan had prepared hazard maps before the Great East Japan Earthquake although only an estimated 20% of people had actually accessed those hazard maps in advance of the event (Ranghieri and Ishiwatari, 2014). One approach to improving risk awareness could be to communicate risk information when a property is rented or purchased. For example, in France, landlords and sellers are required to provide information about any insurance payments made as a result of damage from natural disasters. Such information is also available in Australia and New Zealand, although it is not always automatically disclosed (OECD, 2016). In California, a Natural Hazard Disclosure Law was put in place in 1998 requiring property sellers to disclose information on whether the property is located in a natural hazard zone, including earthquake fault zones and seismic hazard zones. One study of the impact of the law found some evidence that the required disclosure had a negative impact on resale prices for homes in flood hazard zones (the impact in seismic zones was not examined) (Troy and Romm, 2004). Risk-based insurance premiums can also offer an important signal on the level of risk faced by households and businesses as higher premiums would normally be charged in high-risk areas (leading to greater awareness of the level risk).

There is some evidence that the approach to communicating the level of earthquake risk can impact the effectiveness of efforts to enhance risk awareness. A study in Wellington (New Zealand), for example, found that people were more concerned about "an earthquake event with a 10% chance in 50 years" than "an earthquake occurrence once every 500 years" although both represent the same risk level (Henrich, McClure and Crozier, 2015). Using return periods within the life span or property ownership period could have a bigger impact on communicating earthquake risk. In California (United States), a widely-published quote from a prominent scientist suggesting that the San Andreas fault is "locked, loaded and ready to roll" has reportedly had a positive impact on increasing earthquake insurance purchase (Jergler, 2017). Additionally, communicating information on potential tangible impacts, such as the potential number of deaths and amount of damage, may improve the effectiveness of risk communication (Botzen, Kunreuther and Michel-Kerjan, 2015).

Experience with earthquake events can also be an important driver of demand for insurance coverage. For example earthquake insurance take-up rates increased in all 47 prefectures in Japan following the Great East Japan Earthquake (from 48.1% in 2010 to 53.7% by 2011). Similarly, after three major earthquakes occurred in 2011, earthquake insurance take-up increased by 12.5% in Turkey. In Lorca (Spain), premium volumes increased by 13% in 2012 - following the 2011 earthquake - more than double the growth rate in premium volumes at the national level. In California (United States), the take-up level for earthquake insurance increased significantly in the two years following the Northridge earthquake and actually led a number of insurers to restrict the coverage they provided or exit the market altogether as a result of their accumulating exposure to earthquake risk.

Facilitating the purchase of earthquake insurance coverage

In addition to low awareness of earthquake risk, households and businesses may have limited knowledge of the insurance coverage that they have (or may be available) to protect against earthquake damages. When earthquake coverage is only included as an endorsement or add-on to standard residential or commercial property policies, households or businesses may not be aware that they need to purchase this coverage. For example, in Italy, 42% of respondents to a survey believed (incorrectly) that they had earthquake coverage as part of their fire policies (Swiss Re, 2015). Similarly, a recent survey of US homeowners found that 29% believed that their standard home insurance policy covered earthquake damages (Insurance Information Institute, 2017). Therefore, providing clarity on whether or not earthquake is a covered peril in policies offered to households and businesses in earthquake-prone areas could make an important contribution to increasing the demand for that coverage.

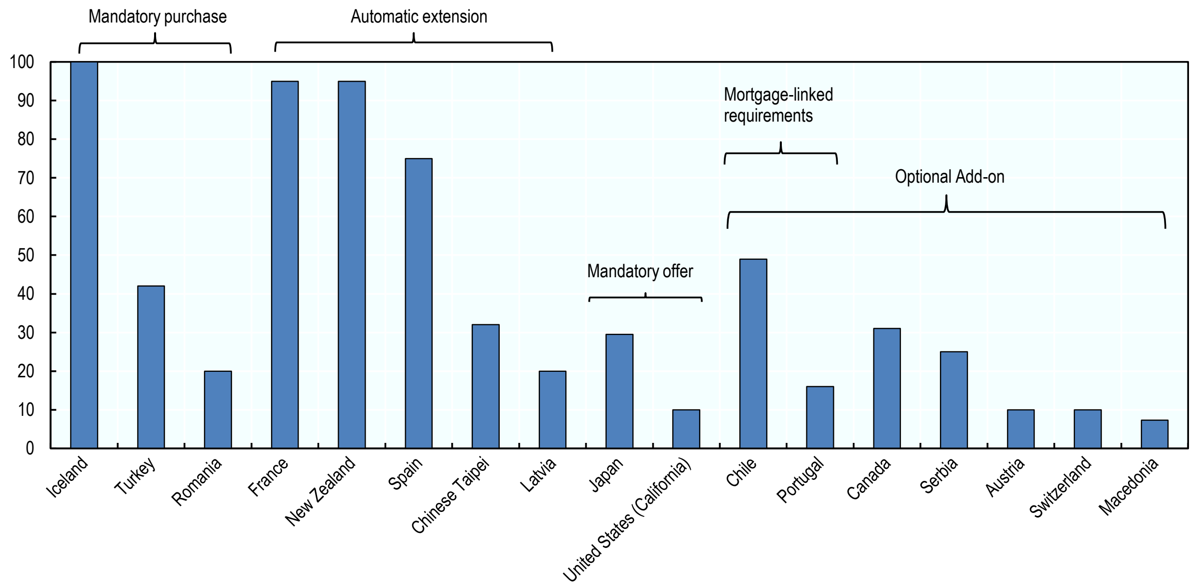
Another approach is to establish requirements around the purchase or offering of earthquake insurance. A number of countries have established various forms of compulsory purchase or offer which has usually had a positive impact on take-up rates (see Figure 5.1):

- ***Mandatory purchase requirements***: Iceland, Romania and Turkey have established mandatory purchase requirements (nationally or in certain regions). In Turkey, the introduction of mandatory purchase requirements has led to an increase in the take-up of residential earthquake coverage from 5% when the

Marmara earthquake hit Turkey in 1999 to 42%. In Romania, take-up rates under the mandatory purchase requirements implemented with PAID in 2012 have reached 20% across the country.

- ***Automatic inclusion of earthquake coverage in standard policies***: France, New Zealand, Spain, Chinese Taipei and the Swiss canton of Zurich automatically include coverage for earthquake risk in standard residential (and sometimes commercial) insurance policies. This has led to levels of take-up in France and New Zealand that approach 100% and take-up levels above 70% in Spain.
- ***Mandatory offer of earthquake insurance***: In Japan and California (United States), insurers are required to offer coverage for earthquake insurance to households that purchase standard property insurance coverage. In Japan, the insurance offered is the earthquake insurance policy reinsured through Japan Earthquake Reinsurance (JER). While optional, policyholders must explicitly decide to opt-out should they not wish to purchase the additional coverage for earthquake risk (i.e. the default option is to include such coverage). In California, the insurer may offer its own earthquake insurance policy or a policy offered by the California Earthquake Authority (CEA). This approach has led to take-up rates above 40% in Japan although take-up rates in California remain near 10%.

Figure 5.1. Residential earthquake insurance penetration based on type of offer/level of compulsion



Source: Responses to the OECD questionnaire on the financial management of earthquake risk.

In other countries, financial institutions that provide mortgage financing may establish requirements for the purchase of earthquake insurance on properties for which they have provided a mortgage (as in Albania, Chile, Colombia, Costa Rica, Latvia, Mexico, Portugal and Russia). Questionnaire respondents from Chile and Portugal, in particular, noted the positive impact of these mortgage-linked requirements on increasing the level of earthquake insurance take-up. In addition to setting requirements, banks (where authorised to provide insurance) can also contribute to greater take-up of earthquake insurance by offering coverage, which provided protection to their borrowers and therefore reduces the risk of loan default caused by severe damage from an earthquake event. In Switzerland, some banks have started offering earthquake insurance coverage with mortgage financing.

These kinds of earthquake insurance requirements can make a contribution to reducing the level of underinsurance although each approach has advantages and disadvantages (see Table 5.1). In addition to reducing the level of underinsurance, increasing the level of take-up also creates a larger and more diversified pool of risks and limits the possibility for adverse selection which should lead to lower premiums (European Commission, 2013) and therefore also contribute to increasing demand for insurance coverage. However, compulsory requirements can be difficult to enforce and may be perceived as a tax. Automatic inclusion of earthquake coverage in standard policies could have adverse implications on the availability of other types of coverage included in standard policies if insurance companies decide to exit the market rather than provide coverage for earthquake risk in high-risk regions. Both mandatory purchase and automatic extension are often supported in practice by public insurance schemes.

Table 5.1. Types of insurance compulsion

	Advantages	Disadvantages
Mandatory purchase	Promotes the expansion of disaster insurance coverage, and the diversity of risks covered, which should help to reduce insurance costs overall. Eliminates the risk of adverse selection (i.e. those who perceive themselves to not be at risk may not purchase insurance, possibly increasing risks in the pool). Counteracts potential behavioral biases, which may otherwise lead to inadequate coverage. Serves to clarify the allocation of disaster costs and reduces the government's implicit contingent liabilities.	May be unpopular and perceived as a tax. May run contrary to the culture of the country and face constitutional constraints (e.g., limit to private autonomy). Enforcement of purchases may be difficult. Given the captive market, the insurance sector may seek to build strong profit margins into premium rates; at the other extreme, inadequate pricing may lead to underwriting losses and drain capital from the industry. Mandated pricing may become overly influenced by other policy objectives.
Automatic extension i.e., automatic inclusion of disaster coverage in basic voluntary property insurance policies	Can be effective if the penetration rate of the underlying basic policies is relatively high, so that they are used as a vehicle to spread disaster insurance coverage. Compared with the mandatory purchase of disaster insurance, this option entails a lower degree of compulsion and may be less unpopular.	May have negative effects on the market for the basic property policy to which the mandatory disaster extension applies if the extension leads to higher premiums or the exit of some insurers that are unwilling to underwrite disaster risk.
Mandatory offer	Ensures the availability of disaster insurance coverage, so that businesses and individuals who are willing to purchase financial protection can do so.	May lead to adverse selection: those who perceive themselves to not be at risk may not purchase insurance, possibly increasing risks in the pool and leading to sub-optimal take-up rates; low risk awareness or cognitive biases may aggravate this effect. If the penetration rate remains very low, there may be inadequate risk pooling.

Source: Adapted from OECD (2012).

Adverse selection can also be reduced - and the creation of a diversified pool of risks achieved - by bundling earthquake coverage with other natural hazard perils as some households and businesses may be more concerned about their exposure to other risks, such as flood. In Germany, earthquake risk is included in optional "*Elementarschadenversicherung*" coverage for natural perils that can be added to residential property policies and has achieved a take-up rate of approximately 40% of German residential properties.

A number of studies of disaster insurance take-up have also found that - while households may initially purchase additional coverage for disaster perils - in the aftermath of an event or to meet mortgage-linked requirements - they will often allow that coverage to lapse over time. The automatic renewal of insurance coverage or multi-year earthquake insurance policies could help address this issue. In Japan, earthquake insurance policies with a tenure of up to five years are available from non-life insurance companies. The multi-year policy can even benefit from an 11% discount if purchased for five years (relative to the cost of a one year contract). According to General Insurance Rating Organization of Japan (2016), the number of earthquake insurance policies written in 2015 was approximately 9.5 million while the number of policies in force in the same year was approximately 16.9 million, implying that approximately 7.4 million policies (44% of the policies in force) were written in previous years for a multi-year tenure. Multi-year insurance also has the potential benefit of reducing the administrative and transaction costs of policies (although any change in the level of risk from year-to-year could not be reflected).

In general, government involvement in compensating the damages incurred by households and businesses will negatively impact the penetration of earthquake insurance and reduce the incentives for taking mitigating actions. To improve the contribution of insurance in covering losses and to reduce the government's contribution in indemnifying damages of earthquakes, financial assistance should be designed to not crowd out private insurance by, for example, limiting eligibility for financial assistance to those that have purchased insurance protection or that are unable to purchase insurance at an affordable cost. For example, in Turkey, eligibility for receiving government assistance is linked to having a valid (compulsory) earthquake insurance policy.

To the extent feasible, governments should also provide clarity on the level of compensation or financial assistance that may be provided to individual households and businesses. Such clarity would allow households and businesses to identify any gaps in their ability to absorb potential losses which could be addressed through the purchase of insurance coverage. It would also reduce any misunderstandings about the potential for government funding to compensate all damages and losses.

Providing premium subsidies

The price of insurance has been demonstrated to be an important factor in purchasing decisions. One survey found, for example, that the cost of the insurance was the most important factor in purchasing decisions for 59% of survey respondents (Ernst and Young, 2014). The price elasticity of demand for insurance (how reactive demand is to changes in the premium level) can provide an indication of the sensitivity of insurance buyers to increases in price. Using data from the California Earthquake Authority, one study found the coefficient of price elasticity of demand to be minus 0.48, implying that a 10% increase in price could lead to a 4.8% decrease in demand (LaTourrette, 2010). The cost of earthquake insurance is likely even more important in lower income countries where households face more significant financial constraints.

Where the affordability of earthquake insurance is a challenge, governments could provide subsidies or tax incentives to reduce the cost of insurance. A number of countries provide implicit subsidies as a result of flat-rate premiums or by establishing premiums for publicly-backed earthquake insurance that is below the level of expected or probable losses. New Zealand, France and Spain have flat (or relatively flat) pricing for earthquake (and other natural disaster) coverage as a deliberate government policy based on the principles of solidarity and sharing of risk across citizens. In Japan, up to JPY 50 000 in income tax deduction is available for policyholders who purchase earthquake insurance.

Subsidised premiums dampen the risk signal inherent in risk-based premium pricing and could reduce (or eliminate) any incentives for policyholders to make investments in risk reduction. Where subsidies eliminate or reduce impediments to insurance affordability and availability among households and businesses, they may also reduce the incentives for risk mitigation or land-use controls at the level of local governments (Douglas, Bowditch and Ni, 2013). The opportunity cost of premium subsidies, which are recurring and have limited (or no) benefit in terms of reducing risk, needs to be evaluated against the alternative use of those funds for investing in risk reduction.

Notes

1 The CEA provides premium discounts for retrofitted structures of 5% for buildings built before 1979 with self-verification; 10% for buildings built between 1960 and 1978 with a completed verification form; and 20% for buildings built prior to 1960.

2 Allocating income to reserves instead of profits would normally reduce the overall level of taxes that a company must pay (which is usually based on profits), other things equal. As a result, tax authorities often establish limits on the amount of funds that can be allocated to reserves.

3 Catastrophe bonds are a form of high-yield bond that contains a provision that may cause the principal or interest payments to be delayed or lost to investors in the event of a specified loss, such as a hurricane or earthquake. The bonds are collateralised with high-quality collateral, reducing counterparty risk, and can be designed to trigger payouts based on actual losses, an index or the physical characteristics of the event. Sidecars (also known as collateralised reinsurance) are special-purpose reinsurers, often established by traditional reinsurers, whose purpose is to provide dedicated collateralised quota-share reinsurance coverage. Industry loss warranties are a type of reinsurance or derivatives contract through which an insurance company can purchase loss protection that is triggered based on the level of industry-wide losses for a given event (Wolfrom and Yokoi-Arai, 2015).

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Chapter 6.

Managing the fiscal cost of earthquakes

This chapter provides an overview of the fiscal costs of earthquake, including the potential increase in expenditure for recovery, reconstruction and financial assistance and compensation as well as the potential decrease in revenues that could accompany reduced economic activity. Examples of measures to reduce the scope of these earthquake-related contingent liabilities are provided along with an overview of the different approaches to funding these costs.

Earthquakes usually have implications for public finances by reducing revenues and increasing the expenses of governments. Governments will normally face costs related to emergency response, reconstruction of public assets, and any compensation and financial assistance provided to sub-national governments, businesses and individuals affected by the event (whether expected or unexpected). Where governments provide insurance, reinsurance or guarantees for earthquake losses, they may also face costs if covered losses exceed any accumulated reserves. Government revenues might also diminish in the wake of an earthquake owing to any contraction in economic activity that leads to lower current and future tax revenues.

The effective financial management of these earthquake-related contingent liabilities requires governments to: (i) evaluate the potential exposures that they face; and (ii) develop an *ex ante* plan (or plans) for managing those exposures, considering the relative roles of investments in risk reduction, risk transfer and *ex post* response as well as the timing of different funding needs. The following sections provide an overview of the potential fiscal costs of earthquakes and different approaches to managing those costs.

The fiscal costs of earthquakes

In the event of an earthquake, governments will likely face significant costs related to emergency response, reconstruction of public assets and financial assistance and compensation, including through public insurance arrangements:

- Governments are generally expected to provide ***emergency relief*** to those affected by an earthquake. These costs are generally small in magnitude relative to reconstruction costs, although require the immediate mobilisation of funds. For example, emergency relief provided in the aftermath of the Great East Japan Earthquake represented less than 1% of total government expenditures for the fiscal year 2011 although was mobilised within three days of the event (Ranghieri and Ishiwatari, 2014).
- The cost of ***repairing and rebuilding public buildings and infrastructure*** damaged by an earthquake (or as a result of secondary perils, such as tsunami or liquefaction) usually accounts for a significant share of *ex post* public expenditures. For example, following the Canterbury earthquakes, the central government faced NZD 2.2 billion in expenditures for the repair and reconstruction of central government assets and the reconstruction of Christchurch city centre, accounting for approximately one third of the central government non-insurance related net earthquake costs (Government of New Zealand, 2017).[1]
- In a number of countries there are also ***public compensation and financial assistance schemes*** that provide support to individuals and businesses to either compensate for the costs of reconstruction or provide financial assistance to mitigate some of the other financial impacts of the event (e.g. emergency needs and living expenses, livelihood/business disruption, etc.). In some cases, these schemes can take responsibility for a significant share of overall reconstruction costs - particularly where insurance coverage is limited. For example, following the Northridge earthquake in California in 1994, where 67% of direct losses were uninsured, federal financial assistance accounted for more than 15% of all direct losses (Petak and Elahi, 2000). Financial assistance programmes aimed at addressing livelihood and business disruption can also involve large costs - in

Japan, economic and social support programs put in place after the Great East Japan Earthquake (such as employment programs, measures to support SMEs, housing grants, and education assistance) cost more than the direct repair and reconstruction of damaged structures (Ranghieri and Ishiwatari, 2014).

- Governments may also face costs as a result of ***public insurance, reinsurance or guarantees*** provided for earthquake losses. As outlined in Chapter 3, public (re)insurance schemes that provide insurance coverage for earthquake risk normally involve a cost-sharing arrangement between government and insurance companies with governments often responsible for peak losses. In Japan (as of 1 April 2016), the government is responsible for an increasing share of losses above JPY 115.3 billion including 50% of aggregate losses between JPY 115.3 billion and JPY 437.9 billion and for 99.7% of losses above JPY 437.9 billion. The government's share of losses resulting from Great East Japan Earthquake under JER's risk sharing arrangement, for example, was 45% of claim payments (Ranghieri and Ishıwatari, 2014).[2] In Chinese Taipei, the government is responsible for 100% of losses above TWD 56 billion up to a ceiling of TWD 70 billion. In Turkey, EUR 250 million is provided to TCIP by the government as excess of loss reinsurance coverage (equivalent to just over 6% of the TCIP's total claims paying capacity).

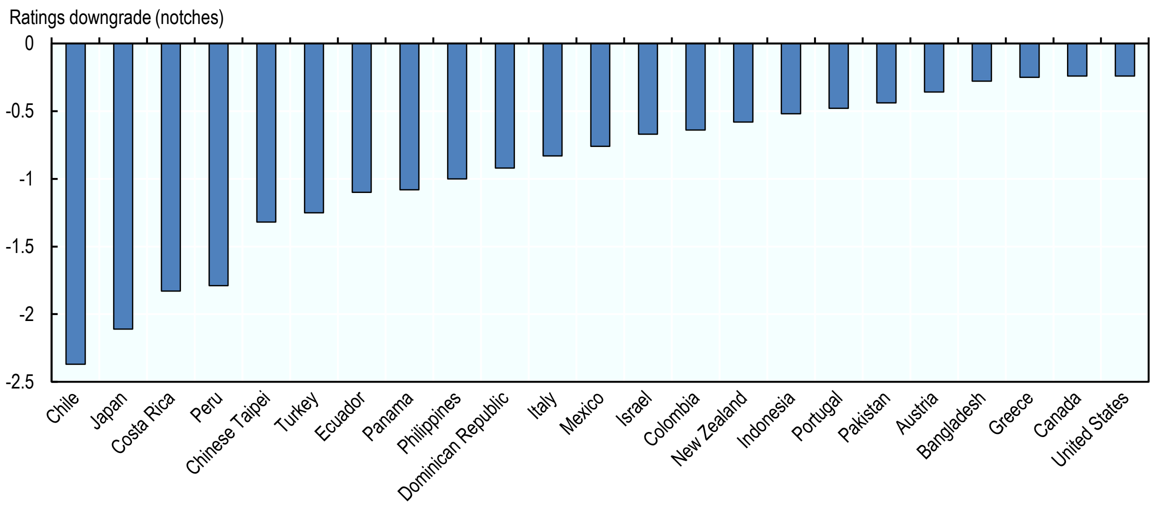
  CCS (Spain) and CCR (France) benefit from an unlimited guarantee from the government should losses exceed their claims paying capacity although neither organisation has made a call on their guarantee as a result of an earthquake. In the case of CCR, the government guarantee was called upon to recapitalise CCR after large losses due to flooding in the Aude area of France in November 1999 and windstorms Lothar and Martin in December of that same year (Michel-Kerjan, 2001). In Romania, although it is not legally required, the government may provide a loan to the insurance scheme (PAID) if a major earthquake depletes the scheme’s funds. In New Zealand, the EQC also has an unlimited government guarantee although government funding was not required in the aftermath of the Canterbury earthquakes. Before the Canterbury earthquakes in 2010 and 2011, EQC had accumulated NZD 5.9 billion in the Natural Disaster Fund (its reserve fund) which, along with proceeds from reinsurance arrangements, allowed it to payout NZD 9.4 billion in claims payments (as of June 2016) (Earthquake Commission, 2016).

- An extreme event could also lead to ***public funding for financial institutions*** faced with losses beyond their capacity to absorb. An extreme event could lead to the failure of insurance companies should claims demands exceed reserves and capital, including proceeds from reinsurance arrangements. Following the 2011 Canterbury Earthquake, New Zealand’s second-largest residential insurer, AMI Insurance was unable to meet its claims obligations for the coverage it had provided leading the government to intervene to settle close to NZD 1.5 billion in outstanding claims through the establishment of a special-purpose claims settlement entity (Southern Response, n.d.). In countries with lower levels of insurance coverage (or high-levels of co-insurance), households and businesses may be faced with costs beyond their capacity to absorb which could lead to defaults on financing provided by the banking sector.

In addition to the increase in government expenditures following an earthquake, governments may face a reduction in tax revenues (often mitigated to some extent by the economic benefits that come with reconstruction activities). Turkey faced a USD 1.2 billion decrease in tax revenues following the Marmara earthquake in 1999, which mainly affected a highly-industrialised area of the country (Akgiray, Barbarosoglu and Erdik, 2003). In California (United States), the Northridge earthquake in 1994 led to a USD 0.86 billion decline in tax revenues affecting federal, state and local authorities (Petak and Elahi, 2000).

The combined impacts of increased expenditures and reduced revenues can lead to deterioration in public finances. When combined with the general reduction in economic growth and export performance that results from economic disruption, a sovereign rating downgrade and increased borrowing costs could result (which can exacerbate the aggregate impact on public finances and also has implications for the development of financial management plans). An analysis of the potential impact of a 1-in-250 year earthquake on sovereign credit ratings found that a number of countries could face material ratings downgrades (one to two notches) as a result of the impact of such an event on public finances (see Figure 6.1) (Standard & Poor's, 2015).

Figure 6.1. Net sovereign rating impact of a 1-in-250 year earthquake



Source: Standard & Poor's, 2015.

Approaches to managing earthquake-related contingent liabilities

Reducing contingent liabilities

There are a number of potential opportunities for reducing earthquake-related contingent liabilities, including through investments in risk reduction (as described in Chapter 5), efforts to reduce the scope of public financial assistance and compensation arrangements and measures to reduce potential liabilities from public (re)insurance arrangements and guarantees.

Public financial assistance and compensation arrangements can make an important contribution to supporting economic recovery (and reducing suffering) among those severely affected by earthquakes. In particular, public financial assistance can act as an important bridge between the occurrence of an earthquake event and the payment of indemnity claims through insurance arrangements which could be delayed, particularly in the event of a significant event given the finite availability of claims adjustment expertise. In Australia, for example, financial support provided through the Australian Government Disaster Recovery Payment and the Disaster Recovery Allowance are meant to provide single payments and temporary income support (respectively) targeted at those that have been severely affected by a disaster event. However, as noted in Chapter 4, more generalised compensation for damage and business interruption is likely to act as a "free" substitute for insurance and therefore act as a disincentive for greater take-up of insurance coverage by households and businesses.

Providing *ex ante* clarity on the scope of potential governmental compensation can have important advantages in terms of ensuring prompt assistance based on established rules and procedures and reducing the potential for unplanned post-disaster assistance. *Ad hoc* financial assistance provided in the aftermath of an earthquake event may be ill-planned, untimely, and overly discretionary, potentially leading to higher-than-expected assistance and discontent over possible inequities in compensation. Also, in the absence of well-defined parameters surrounding this assistance, individuals and businesses may have a strong expectation of post-disaster aid, even where governments intend to provide only minimal assistance. An OECD (forthcoming) study on the management of disaster-related contingent liabilities found that countries with a low level of *explicit* contingent liabilities (i.e. payment obligations based on pre-defined legal, contractual or policy obligations and commitments) often face higher levels of *implicit* contingent liabilities as low levels of commitment-based financial assistance and compensation can increase the level of political pressure for governments to do more. This will be exacerbated where insurance coverage is low, leaving significant levels of uninsured losses to be absorbed by households and businesses.

A significant component of public expenditure after an earthquake event relates to the repair and reconstruction of publicly-owned assets and can be reduced through the purchase of insurance for these assets:

- In a few countries, public assets are covered against earthquake risk by a public insurer. In Iceland and Spain, the public insurance provider for catastrophe risks (ICI and CCS) provides insurance coverage for publicly-owned assets against the same set of risks (including earthquake).[3] In the Philippines, the national Government Service Insurance System (GSIS) provides coverage for public assets (OECD, 2015). In Australia, federally-owned public assets are insured through a dedicated insurance scheme (ComCover) while a number of states and territories have public insurers mandated to provide insurance for public assets. While not reducing public sector contingent liabilities directly, these types of approaches can facilitate the transfer of risks to reinsurance or capital markets by establishing a (somewhat) diversified pool of assets. GSIS, for example, has secured reinsurance coverage for earthquake and other natural disaster perils for the insurance coverage it has provided for public assets.

- In many countries, public assets are normally covered by private insurance (e.g. Latvia, Macedonia, New Zealand, Serbia), sometimes as a result of a requirement imposed on national and/or local government agencies (e.g. Colombia, Peru). In some countries, insurance-related requirements have been specifically established for cultural heritage. In Costa Rica, the National Risk Management Plan 2016-2020 includes an expectation for cultural heritage assets to be insured. In Mexico, the Integral Insurance Program on Heritage Properties of the National Institute of Anthropology and History (INAH) examines on a case-by-case basis whether insurance is required for the protection of individual cultural heritage properties. In Russia, insurance mechanisms to provide financial protection for monuments and cultural objects are being developed.

Similar to the case of privately-owned assets, governments should consider ways to ensure that sub-national governments have appropriate incentives in terms of the financial management of earthquake risks to assets for which they are responsible. If the national government takes on substantial responsibility for the cost of rebuilding sub-national public assets, sub-national governments may be reluctant to purchase insurance or even invest in risk reduction as these costs would need to be borne in full by sub-national governments. In Australia, the Attorney General has the authority to review the insurance arrangements implemented by sub-national governments, make recommendations on changes to those arrangements and penalise states and/or territories that do not comply with those recommendations, including by reducing the share of reconstruction costs paid by the national government.

For countries that provide public insurance for earthquake risk, the residual public sector contingent liability can be minimised by maximising the share of losses covered by the private (re)insurance sector - either by limiting the coverage provided by the public insurance scheme or transferring a portion of the public insurance scheme's exposure to reinsurance or capital markets. As noted in Chapter 3, a number of public insurance schemes make use of international reinsurance and capital markets, including EQC, ICI and PAID (reinsurance coverage), TCIP (catastrophe bonds) and CEA (reinsurance and catastrophe bonds - although CEA does not benefit from a government guarantee). JER retrocedes its exposure to domestic insurance companies and also makes adjustments to cost-sharing arrangements with the private insurance sector based on changes in insurance sector capacity. CCR and CCS do not transfer any of their exposure to international markets although CCR limits the coverage it provides to 50% of the amount underwritten by the primary insurers. CEA and JER also have the ability to prorate claims if losses are higher than their capacity or ceiling. In the case of CEA, if earthquake claims exceed its payment capacity, a premium surcharge of up to 20% will be charged to all policyholders in order to provide additional funds. Should the additional resources still be insufficient to pay claims, payments to policyholders would be prorated and only paid out in full when sufficient funds, such as from future premiums, become available (McAnaney et al., 2016).

Funding contingent liabilities

There are a number of options for funding the fiscal costs of disasters. Governments may choose to finance these costs through existing budgets and any reserve funds or transfer some of their exposure to insurance or capital markets. These different approaches to financing fiscal costs can be classified as either *ex ante* (arranged in advance) or *ex post* (arranged after the event) funding (see Table 6.1).

Table 6.1. Approaches to financing fiscal costs

Ex ante funding arrangements	*Ex post* funding arrangements
Dedicated reserve fund	Supplemental budget reallocation
Contingent credit/guarantee facility[1]	Debt financing/borrowing
(Re)insurance arrangement	Supplemental taxation
Catastrophe bond, other CAT-linked securities	Multinational international borrowing
Alternative risk transfer instruments	International aid

1. While a contingent credit/guarantee facility is arranged *ex ante*, the costs are absorbed *ex post*.
Source: Adapted from OECD 2013.

Governments may make *ex ante* arrangements for financing the fiscal costs expected to result from an earthquake in advance of the occurrence of such an event by creating a reserve fund (or other form of advance budgetary allocation) or by entering into borrowing or risk transfer arrangements in order to access funding triggered by the occurrence of an event:

- In many countries, reserve funds have been established as either the primary means to finance the fiscal costs that will materialise with the occurrence of an earthquake or as part of a broader financial strategy for managing fiscal impacts. In the Philippines, a Disaster Risk Reduction and Management (DDRM) Fund is funded through annual allocations from the national budget while in Japan, a Contingency Reserve is available for addressing unexpected financing needs (and was used to provide funding following the Great East Japan Earthquake). In the United States, a dedicated amount of federal funding is allocated to government departments and housing authorities on an annual basis to manage the cost of rebuilding of public housing based on the expectation that some reconstruction costs will materialise every year.
- A number of countries have arranged contingent credit lines that are triggered based on the occurrence of a disaster (usually based on the declaration of a state of emergency). Such facilities can be secured from multilateral development banks (World Bank, Inter-American Development Bank) and bilateral development agencies (Japan International Cooperation Agency). The credit lines can provide an important source of early financing to meet recovery needs which is particularly crucial for countries with more limited access to international capital markets. Many of the providers also attach conditions related to the implementation of disaster risk management improvements before entering into loan agreements as a means to maximise the impact of this funding on disaster risk reduction. The Philippines has secured a Catastrophe Deferred Drawdown Option (Cat-DDO) contingent credit line of up to USD 500 million to provide immediate access to liquidity upon the declaration of a state of emergency (OECD, 2015) as well as a separate credit line from the Japan International Cooperation Agency (Laureano, 2015). Costa Rica secured a contingent credit line of USD 65 million from the World Bank for the period between March 2009 and October 2011, which was drawn down in the amount of USD 24 million following the earthquake in 2009. Contingent credit lines do not involve a transfer of risk to the lending institution meaning that the costs will be absorbed through repayments made after the event (*i.e.*, costs are absorbed *ex post*, unlike in the case of a reserve fund or (re)insurance/capital market risk transfer arrangement).

- Governments may also transfer some of their exposures to (re)insurance and capital markets, including by insuring public assets and transferring some portion of the exposure acquired through public insurance schemes (as described above). Governments can also enter into (re)insurance or other risk transfer arrangements to transfer general government contingent liabilities. In Mexico, catastrophe bonds have been issued and reinsurance arranged to provide funding for the recovery and reconstruction expenditures of FONDEN, the Government of Mexico's fund for reconstruction of public assets and low-income housing. A series of catastrophe bonds have been issued since 2006 to provide protection against earthquake and storm losses triggered based on the physical parameters and location of the event. In 2006, FONDEN issued a USD 160 million catastrophe bond (CatMex) to transfer earthquake risk to international capital markets. In 2009, FONDEN issued a second catastrophe bond for an amount of USD 290 million of which USD 140 million was allocated for earthquake damages. In 2012, FONDEN issued a third catastrophe bond of USD 315 million which expired in 2015 (World Bank, 2013). The most recent issue, in 2017, provides USD 150 million in coverage for earthquake risk to 2020 (World Bank, 2017). The reinsurance arrangement provides up to USD 400 million in protection that is triggered once FONDEN costs exceed USD 56 million. In 2018, the World Bank issued a series of five catastrophe bonds to provide financial protection to Chile, Colombia, Mexico and Peru against earthquake risk. The catastrophe bonds (USD 500 million for Chile, USD 400 million for Colombia, USD 160 million and USD 100 million for Mexico and USD 200 million for Peru) would be triggered as the result of an earthquake of a given magnitude and would provide the affected country with funding to support recovery and reconstruction (World Bank, 2018). In the Philippines, a catastrophe swap transaction has been structured with the assistance of the World Bank to provide approximately USD 206 million in financial protection for damages to public assets and other public recovery and reconstruction costs from a major earthquake or typhoon, triggered on a parametric basis (Artemis, 2017). In the Caribbean and Pacific islands, regional pooling mechanisms have been established to provide quick payments to participating governments to fund initial recovery efforts (see Box 6.1).

Governments may instead choose to manage some or all of the fiscal costs of earthquakes on an *ex post* basis, by re-allocating budgetary funds to recovery and reconstruction needs, imposing new taxes to finance these costs and/or by borrowing from international capital markets or multilateral development banks. For governments with robust access to international capital markets, this approach may have limited repercussions on the cost of borrowing. Low income countries may also have access to international assistance to fund recovery and reconstruction costs. Similarly, countries with the capacity to impose new taxes without significant negative implications for economic performance may consider such an approach as well.

Many governments affected by recent earthquakes have used *ex post* financing approaches to fund fiscal costs. Following the Great East Japan Earthquake in 2011, the Japanese government introduced three supplementary budgets of approximately JPY 15 trillion for the purpose of covering emergency response and reconstruction. In addition to budgetary allocations, the Japanese government issued JPY 14.2 trillion in reconstruction bonds to finance some reconstruction with the bulk of repayments to be funded through tax increases. Personal income tax rates were increased by 2.1% starting in 2013 for 25 years, a planned 5% corporate tax reduction was postponed and a JPY 1 000 per capita increase in local taxes was introduced (Ranghieri and Ishiwatari, 2014). After the Marmara earthquake, value added tax was raised from 15% to 17% in Turkey, generating additional revenues of USD 5.7 billion in 2000 to fund reconstruction (Akgiray, Barbarosoglu and Erdik, 2003).

Box 6.1. Regional risk pooling arrangements

In a number of regions, national governments and multilateral development banks have collaborated on the establishment of regional risk pooling arrangements as a means to mutualise risk and create economies of scale for accessing international capital and/or reinsurance markets. Among these regional risk pooling arrangements, the Caribbean Catastrophe Risk Insurance Facility (CCRIF) and the Pacific Disaster Risk Financing and Insurance (PDRFI) provide coverage for earthquake risk:

- CCRIF provides coverage to its member governments to reduce the short-term cash flow challenges that usually accompany earthquake, hurricane and excess rainfall events. CCRIF has paid around USD 8.7 million for earthquake events, including USD 7.7 million for the Haiti earthquake in 2010 (CCRIF, 2015).
- PDRFI was established with the support of the World Bank and a grant from the Japanese government with the aim of providing coverage to participating countries against earthquake, tsunami and tropical cyclones based on a parametric trigger. By pooling the more diverse set of risks across participating countries, it enables the PDRFI to benefit from cost reductions in accessing (re)insurance markets (OECD, 2015).

This kind of approach can also be implemented within countries as a means of creating a diversified pool of risks that can be more affordably transferred to reinsurance or capital markets. In New Zealand, a mutual risk pool has been established by a number of local governments for underground infrastructure assets. The pool has accumulated approximately NZD 20 million in reserves and has entered into a reinsurance arrangement that provides an additional NZD 40 million in financial protection.

Assessing the costs and benefits of different approaches to fiscal management of earthquake risk

Effectively managing the fiscal costs of earthquakes requires consideration of the magnitude of explicit and implicit contingent liabilities that a government may face from a range of potential events, considering both the impacts of historical events as well as forward looking assessment of potential events, including the possible damages and losses from secondary perils such as tsunami and liquefaction. Once this exposure is quantified, governments need to assess the timing of financing requirements for different phases of a disaster (e.g., relief, recovery and reconstruction). While relief and recovery operations require a limited amount of resources that can be mobilised immediately after a disaster, reconstruction will generally require greater resources although in the medium to long-term (Ghesqueire, 2010).

The costs and benefits of *ex ante* investments in risk reduction and risk financing should be taken into account when developing a financing approach to manage the fiscal costs of earthquake risk. In general, for events with frequent occurrences and low to medium impacts, risk mitigation investments can be more cost-effective than risk transfer. Infrequent disasters with medium to high-level impacts may be better managed through the use of risk transfer tools. However, extreme events with very low probabilities of occurrence but very high impacts may be too expensive for governments to transfer to insurance markets (Mechler, Mochizuki and Hochrainer-Stigler, 2011).

Consideration should also be given to the timing of access to different sources of funding relative to funding needs at different phases of recovery and reconstruction. The main advantage of *ex ante* instruments is that they are a secured source, allowing (relatively) quick disbursement after an event. On the other hand, *ex post* instruments can take some time to mobilise depending on the arrangement. Short-term liquidity requirements can be met by reserve funds and contingency credit arrangements. For longer-term funding needs, such as reconstruction costs, governments have more flexibility for mobilising resources *ex post*, for example through debt issuance and/or supplemental taxation. The assessment of various approaches also needs to consider the incentives created by these approaches and the impact of those incentives on ultimate costs. For example, a reliance on *ex-post* financing of disaster costs may also lead to a bias against *ex ante* mitigation (Productivity Commission, 2014).

Notes

1. In its accounting of its costs related to the Canterbury earthquakes, the Government of New Zealand also includes just over NZD 7 billion for EQC insurance claims and NZD 1.4 billion for claims payments to customers of a failed insurer (AMI).

2. The Great East Japan earthquake led to JPY 1.2 trillion in insurance claims for JER, of which 42% was absorbed by the private insurers, 13% was absorbed by JER and 45% was absorbed by the government.

3. In Spain, the coverage provided for publicly-owned assets is the same as for privately-owned assets (i.e. as an automatic extension to standard fire insurance policies).

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Earthquakes are one of the most destructive natural perils and can lead to severe economic, social and environmental impacts. Rapid urbanisation, the accumulation of assets in seismic areas – and, to some extent, increasing induced seismicity – have led to an increasing amount of exposure to earthquake risk in many parts of the world. The financial management of earthquake risk is a key challenge for individuals, businesses and governments in developed and developing countries, and the G20 Finance Ministers and Central Bank Governors and APEC Finance Ministers have recognised the importance of building financial resilience against these risks. This report applies the lessons from the OECD's analysis of disaster risk financing practices and the guidance in the OECD Recommendation on Disaster Risk Financing Strategies to the specific case of earthquakes. It provides an overview of the approaches that economies facing various levels of earthquake risk and economic development have taken to managing the financial impacts of earthquakes.

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