ECONOMICS OF DISASTER RECOVERY AND EARTHQUAKE INSURANCE: FIVE ESSAYS ON NEW ZEALAND

by

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Abstract

The Canterbury earthquake sequence (2010-2011) was the most devastating catastrophe in New Zealand's modern history. Fortunately, in 2011 New Zealand had a high insurance penetration ratio, with more than 95% of residences being insured for these earthquakes. This dissertation sheds light on the functions of disaster insurance schemes and their role in economic recovery post-earthquakes.

The first chapter describes the demand and supply for earthquake insurance and provides insights about different public-private partnership earthquake insurance schemes around the world.

In the second chapter, we concentrate on three public earthquake insurance schemes in California, Japan, and New Zealand. The chapter examines what would have been the outcome had the system of insurance in Christchurch been different in the aftermath of the Canterbury earthquake sequence (CES). We focus on the California Earthquake Authority insurance program, and the Japanese Earthquake Reinsurance scheme. Overall, the aggregate cost of the earthquake to the New Zealand public insurer (the Earthquake Commission) was USD 6.2 billion. If a similar-sized disaster event had occurred in Japan and California, homeowners would have received only around USD 1.6 billion and USD 0.7 billion from the Japanese and Californian schemes, respectively. We further describe the spatial and distributive aspects of these scenarios and discuss some of the policy questions that emerge from this comparison.

The third chapter measures the longer-term effect of the CES on the local economy, using night-time light intensity measured from space, and focus on the role of insurance payments for damaged residential property during the

local recovery process. Uniquely for this event, more than 95% of residential housing units were covered by insurance and almost all incurred some damage. However, insurance payments were staggered over 5 years, enabling us to identify their local impact. We find that night-time luminosity can capture the process of recovery; and that insurance payments contributed significantly to the process of local economic recovery after the earthquake. Yet, delayed payments were less affective in assisting recovery and cash settlement of claims were more effective than insurance-managed repairs.

After the Christchurch earthquakes, the government declared about 8000 houses as Red Zoned, prohibiting further developments in these properties, and offering the owners to buy them out. The government provided two options for owners: the first was full payment for both land and dwelling at the 2007 property evaluation, the second was payment for land, and the rest to be paid by the owner's insurance. Most people chose the second option. Using data from LINZ combined with data from Stats NZ, the fourth chapter empirically investigates what led people to choose this second option, and how peer effect influenced the homeowners' choices.

Due to climate change, public disclosure of coastal hazard information through maps and property reports have been used more frequently by local government. This is expected to raise awareness about disaster risks in local community and help potential property owners to make informed locational decision. However, media outlets and business sector argue that public hazard disclosure will cause a negative effect on property value. Despite this opposition, some district councils in New Zealand have attempted to implement improved disclosure. Kapiti Coast district in the Wellington region serves as a case study for this research. In the fifth chapter, we utilize the residential property sale data and coastal hazard maps from the local district council. This study employs a difference-in-difference hedonic property price

approach to examine the effect of hazard disclosure on coastal property values. We also apply spatial hedonic regression methods, controlling for coastal amenities, as our robustness check. Our findings suggest that hazard designation has a statistically and economically insignificant impact on property values. Overall, the risk perception about coastal hazards should be more emphasized in communities.

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I take refuge and offer everything to the Triple Jewels of Buddhism, for Buddha's goodness is infinite; his presence is constant throughout my life.

Declaration

I declare that this thesis, which I submit to the Victoria University of Wellington for examination in consideration of the award of a higher degree, the Doctor of Philosophy is my own personal effort.

I have not already obtained a degree or diploma in the Victoria University of Wellington or elsewhere based on this work.

Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

Cuong Nhu Nguyen

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'Most respectfully dedicated to my beloved parents and my teachers'

Chapter 1

Introduction

1.1 Background and Context

Disasters have been studied by among economists for long time (Dacy & Kunreuther, 1969; Albala-Bertrand, 1993). Nevertheless, the research field has only developed intensively since the 2000s. In general, disasters are influenced by economic forces such that "the very occurrence of disasters is an economic event" (Cavallo & Noy, 2011).

The existing literature of economics disasters are divided to different branches. They include the impacts of direct damage, the impact of indirect losses (micro and macro level), measurement of disaster risks, disaster risk reduction and mitigation policy, disaster insurance, and economics of climate change. The majority of the previous empirical studies are cross-national. However, regional- or event- specific research provides larger practical significance. As most of decisions to allocate scare resources to affected areas are undertaken by the central government or NGOs. Moreover, the sub-national studies produce useful insights in planning and policy-decisions pertaining to disaster resilience, recovery and climate change adaptation.

For the reasons cited above, this dissertation aims to shed light on earthquake insurance systems, risk perception and household recovery post-earthquake. New Zealand, one of the most exposed countries to earthquake, provides a good case study. The country is located at the starting point of the Pacific Ring of Fire, making it prone to geologic hazard. Historically, New Zealand has experienced many major earthquakes in both its North and South islands (GNS, 2016). Fortunately, the country has high earthquake insurance penetration rate for businesses and residential homeowner. Thus, New Zealander's expectations of having full replacement insurance have been accepted as normal practice both for residential and for commercial cover.

New Zealand is considered to be a first world economy with a high living standard, a stable and dependable governance framework, good aseismic engineering design practices, good construction and building practice with reliable material standards and little corruption of inspection services. However, the Canterbury earthquake sequence, which occurred in 2010 and 2011, came as a major test to the economy at both the regional and national level. The aim of this thesis is to contribute towards understanding earthquake recovery and the role of earthquake insurance. The hope is that this research will provide useful insights for future changes in New Zealand's Earthquake Commission Act 1993.

1.2 Rationale and Objectives

This dissertation comprises five main parts that are in Chapter 2 to 6. Each of these chapters is a separate and complete paper by itself; each has a different focus but with complementary objectives to the other chapters. These empirical studies for New Zealand explore the earthquake insurance, risk perception and the recovery process at the household level. These information gaps in the literature motivated this work.

In chapter 2, we analyze the earthquake insurance market globally, in both demand and supply channels. Then we explain the structure and coverage of several widely known insurance schemes. We also describe the contribution of insurance into recovery post- major earthquakes by providing case studies.

Chapter 3 focuses on the destructive Canterbury Earthquake Sequence (CES), which occurred in the South Island of New Zealand in 2010 and 2011 as our case study. We also analyze three similar public-private partnership insurance programs for earthquake risk in New Zealand, Japan and California in the USA. We then examine the difference in outcomes if the Japanese or Californian earthquake insurance system had been in place.

Using the same case study - the CES, chapter 4 investigates how insurance claim payments for damaged residential property, and specifically their timing and type, affect the recovery process of the local economy. In other words, we aim to measure the longer-term economic effect of insurance payments post-major earthquake event, using satellite night-time light intensity as a proxy measure for economic activity.

In chapter 5, we study the drivers of homeowner's decisions on financial offer options in the buyout process, as carried out by the government. We quantify the peer effect on individual's decision, using data from the Christchurch residential red zone buyout process. Finally, chapter 6 examines whether prices of coastal properties change when more/less information becomes available about the property-specific consequences of future sea level rise (SLR). In other words, we investigate the risk perception of potential homeowners toward coastal hazard risk.

Chapter 2

Insurance for Catastrophes: Why are Natural Hazards Underinsured, and Does It Matter?

2.1 Introduction

Natural disasters have adverse consequences on people and the economy. A combination of effective mitigation and coping strategies, decreasing both exposure and vulnerability to disasters, can reduce their detrimental impact. Further policy choices can reduce the consequent losses to the economy in the aftermath of catastrophic events. Although constituting no panacea, the evidence suggests that insurance and similar financial risk transfer instruments enable improved recovery and thus increase resilience (UNFCCC, 2008; IPCC, 2012).

However, the literature also suggests that insuring catastrophic risks is complex and not easily achieved (Skees & Barnett, 1999; Hazell, 2001; Kunreuther & Michel-Kerjan, 2014). A recent evaluation, for example, suggests that if a 50% of insurance coverage were in place, disaster impact on growth caused by a very severe (1 in 250 years) disaster can be reduced by as much as 40% (S&P, 2015a, 2015b). Still, a survey commissioned by the World Bank in 2009 reported that insurance covers less than 10% of disaster losses in developing countries (Cummins & Mahul, 2009). In developed countries, the figure is higher, though only about 40% of disaster damages are typically insured.

Here, we aim to elucidate the obstacles that appear to reduce both the supply and demand for insurance and that may explain the current low levels of disaster insurance coverage globally, and the evidence that supports these hypotheses. We describe the formal insurance programs implemented by governments, the private sector and multilateral/regional organizations that aim to address several of these impediments to insurance adoption.

In addition to investigating the availability of insurance products, we also analyze the limited evidence about the performance of insurance systems in the aftermath of disaster events. We end by summarizing some of the many questions that we think are necessary to answer in order to expand insurance coverage globally, and specifically in lower income countries where insurance is largely absent.

Different types of disaster insurance products are available globally. Some examples are government supported flood insurance in the United States and in the UK, micro-insurance for crop losses in Bangladesh and India, earthquake insurance in New Zealand and Turkey, tropical cyclone sovereign insurance for the Caribbean and Pacific island countries, drought sovereign insurance in Sub-Saharan Africa, and agricultural insurance in Europe. To narrow our discussion, we focus in this chapter on only a type of insured catastrophic hazards: residential earthquake insurance. With this focus, we seek to provide examples of the complexity of catastrophic-risk sharing mechanisms in urban areas (earthquake insurance), and in rural areas (agricultural insurance), and in higher and lower income countries.

Earthquakes are a very significant hazard in many countries, in particular around the rim of the Pacific Ocean, in mountainous Central Asia and the Northern South Asian subcontinent, and in the Mediterranean. Other regions may not experience very strong earthquakes but in some areas very high vulnerability make them equally risky (e.g., Haiti in 2010). Coastal regions elsewhere are exposed to tsunamis generated by earthquakes (even if far away). Mortality from earthquakes can be very high, with more than half a million casualties in the three most lethal events since the turn of the century (2004 in Indonesia, 2008 in China, 2010 in Haiti). Earthquakes also destroy large amounts of assets, as the costliest disaster in recorded history, the 2011 earthquake in Japan, demonstrates.[1]

Given these observations, it is not surprising that risk transfer tools, and especially insurance, play a significant part in policies dealing with earthquake risk. Here we focus on this sector and describe the reasons that are still impeding the many ways in which insurance can provide on its promise to reduce and transfer risk.

[1] The cost of the earthquake in Japan was mostly associated with damage from the tsunami that was generated by the earthquake, and to a lesser extent by the Fukushima nuclear meltdown that was triggered by the loss of power caused by the earthquake and tsunami damage.

We start by focusing on the demand for insurance by residential households (for earthquake cover). We then analyze the supply of earthquake insurance and the barriers that insurance organizations (private and public) face in providing adequate coverage. We then describe some of the existing insurance schemes for both risks, and continue with the very limited available descriptions of the actual performance of these schemes in the aftermath of catastrophic events. We conclude with some thoughts about future research directions.

2.2 Demand for Earthquake Insurance

Historically in California, a region very exposed to earthquake risk, there has been very little earthquake insurance. For the 1971 San Fernando earthquake, for example, none of the damaged residential properties had insurance cover (Anderson & Weinrobe, 1986). Rates of earthquake insurance coverage today are still very low; with the most recent data suggesting only about 13% of residential properties have cover. Prices for earthquake insurance are high, and local homeowners appear unwilling to purchase cover because of ambiguity in prices, disaster losses, and the probability of occurrence (Palm, 1981; Palm & Hodgson, 1992; Kunreuther & Pauly, 2004). Underinsurance, though, is not unique to California, and is found in other high risk places (Gurenko et al., 2006).

The decision whether to purchase insurance is influenced by people's perceptions of risk, which is often formed by their personal experience. For very low frequency but destructive events, this leads to an underestimation of risk before a disaster occurs, and over-estimation of such risks in the immediate aftermath of a disaster (Hertwig et al. (2004). Browne and Hoyt (2000) estimate people's risk perception based on previous experience with floods, and concluded that there is a positive relationship between risk perception and demand for insurance. This mechanism is especially important for earthquake events, and is somewhat distinct from insurance for more frequent events that are covered by agricultural insurance (or floods). For example, there was a 72 per cent increase in earthquake insurance purchases following the 1989 Loma Prieta earthquake (Palm, 1995).

Behavioral economics suggests several reasons why we observe this. People assess the probability of an event by how often examples of disaster occurrence they can remember; i.e., 'availability bias' (Tversky & Kahneman, 1991; Lieder et al., 2014). Additionally, following a disaster, people focus more on pursuing emotion-related goals such consolation, reduction in anxiety and avoidance of regret (Finucane et al., 2000; Loewenstein et al., 2001). The purchase of an insurance policy can satisfy these goals, but eventually these interests in reducing anxiety and avoiding regret weaken and homeowners become, once again, less inclined to purchase cover. Some individuals even cancel their insurance policy after several years because they find it difficult to justify the spending on premiums that have not been paid on (Hogarth and Kunreuther (1995)). Policyholder, in a sense, tends not to follow the maxim that "the best return on one's insurance policy is no return at all".

2.3 Supply of Earthquake Insurance

As is true for any type of insurance, insurers need to make sufficient profit to generate returns to their shareholders in order to attract capital. Kunreuther and Michel-Kerjan (2014) state that one condition must be satisfied to ensure the availability of coverage against a natural catastrophe: the ability to evaluate the probability of event's occurrence and predict the loss in the case of adverse trigger event. Although there are constantly advancements in seismic science and loss estimation modelling, these forecast tools are yet to reduce the uncertainty to an acceptable level (from an insurance perspective) so that insurance can be offered without major subsidies but priced affordably.

Nevertheless, insurance companies may be reluctant to offer earthquake coverage even when both insurability conditions are met. Following the 1994 Northridge earthquake, insurers suffered losses of $US21.7 billion. After this costly event, affected private insurers decided not to offer earthquake coverage at any price, despite the existence of a significant demand for this insurance product in California.

Even risk information that is potentially available is very costly to collect. For example, in most cases the quality of soil/rock base on which housing is located is largely unknown, as is the likelihood of earthquake-induced liquefaction. This information is very costly to collect, so insurers (private or public) have to rely on very limited information and find it difficult to set risk-informed insurance premiums. This problem is maybe uniquely significant for earthquake insurance. For instance, California public earthquake insurance scheme (CEA) charges the same premium rates for areas with different seismic risks (as do most other public schemes). This creates adverse selection. Homeowners who live in earthquake-prone areas are more likely to purchase the CEA policy. This forces the CEA to charge high premiums and drive take-up rates down (Lin, 2014).

Correlated risk, a problem we already identified as plaguing agricultural insurance, is also significant for earthquake risk. Some of the largest insurance events in the past few decades were associated with earthquakes (in particular the 2011 East Japan earthquake, the 2010-11 earthquakes in New Zealand and the 1994 one in California). Because of this correlated risk among insured households and businesses, insurers are required to hold additional liquid capital, and thus significantly increase their costs.[2]

2.4 Existing Insurance Markets

The market for earthquake insurance is even less developed than other type of insurance for almost all countries (except, maybe, in New Zealand). The impact of an earthquake can be enormous, but there is still limited coverage for earthquake risk even in very earthquake prone places like Japan and the West Coast of the United States. In middle- and low-income countries, almost no earthquake insurance is available. For instance, the 2008 Sichuan earthquake in China caused $US125 billion in losses but less than half a per cent of that was insured. In the 2010 Haiti earthquake, only 3 per cent of disaster losses were covered by insurance.

Kunreuther (2015) argues that the market failures in the case of disaster risks can be remedied through the design of Public-Private Partnerships (PPP) in insurance market. In these arrangements, the private insurance companies can be providing claim services, marketing/distribution, responsibility for some tranches of the cover capacity, or some combination of these. The government may act as the primary insurer (e.g., Australia, Denmark, Mexico, and Poland) or by offering reinsurance coverage for larger losses (e.g., Japan, France and Indonesia). In addition, some governments take a "last resort" guarantor role that ensures the insuring entities will always meet all their obligations to cover the disaster risks (e.g., Spain and New Zealand).

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[2] AMI Insurance (AMI) was the second largest residential insurer in New Zealand. Because of its high market share in the affected region (35 per cent), the private insurer was exposed to a loss of $NZ1.8 billion following the 2010-11 Canterbury earthquake sequence. However, AMI only had $NZ300 million in capital reserves. Consequently, New Zealand Government had to bail out AMI by settling $NZ 1.5 billion of AMI earthquake claims, administrated through a state-owned entity, Southern Response.

PPP insurance systems can overcome some of the issues associated with asymmetric information if they are carefully designed, and by making cover mandatory (or near enough to it), they can also overcome some of the demand constraints. A PPP insurance scheme can charge risk-based premiums, set official standards and regulations, introduce education and applied research programs that help enhance resilience in the community, and also reduce costs through economies of scale and cheaper access to capital.

The main rationale for large public investment is usually to overcome market failures in insurance markets. These include: covariate risk, asymmetric information, limited access to reinsurance market due to small scale, and lack of public databases and risk models to support actuarial calculations.

The question that then needs to be asked is whether it is in the public interest to overcome these market failures. Only if the answer is positive, should one then consider what are the exact failures that matter, and what would be the best way for the public sector to overcome them. The answer to this primary question is not necessarily obvious.

The 'family' home is typically by far the largest asset that households own, so that the public interest in sustaining this investment and insuring it in the face of catastrophic risks might be easier to identify. If an earthquake insurance scheme supports this goal of financially protecting the largest asset owned by (most) homeowners, then it also prevents these homeowners from impoverishment if a catastrophic event occurs.

Clearly, however, homeowners are not the most vulnerable part of society, and therefore a decision to provide a public-sector-financed insurance scheme also has distributional implications. For earthquake (and flood) publicly-provided residential insurance, these distributional impacts are distinctly regressive, though the extent of this regressiveness is rarely measured or even acknowledged (Owen & Noy, 2017).

A related question is whether the government itself needs to purchase insurance for the assets it owns (or for other liabilities it might incur if a catastrophic event were to occur). Again, there are distributional concerns here, especially with respect to who will pay for the indemnified damages, and what is the spatial distribution of the risk. If the risk is localized sufficiently, the central government has no need to further diversify its portfolio of assets, though that may be different for a local government entity that owns assets.

The risk of earthquakes is higher only in some specific regions, especially the Pacific Rim (on both sides of the Pacific), the Alpide belt which stretches through the Mediterranean and the Middle East to the Himalayas, and the Western edge of Indonesia. In order to contribute to their seismic resilience, many countries in these higher risk regions introduced earthquake insurance systems. In low risk and high income areas, the private insurance sector is typically willing to sell earthquake insurance (e.g., Israel), but in higher risk locations the earthquake insurance programs have deep public sector involvement. Here, we focus on the biggest programs to date: in Japan, Turkey, California, and New Zealand.[3] Other high-risk regions do not yet have very well-developed earthquake insurance markets (e.g., the North-West Coast of the United States). We describe these arrangements chronologically based on the time they were introduced.

2.4.1 New Zealand Earthquake Commission (EQC)

New Zealand is seismologically very active. There are 15,000 earthquakes in New Zealand every year, although most are not large enough to be felt.

[3] Nguyen and Noy (2019) compares the three programs in high-income countries (US, Japan, and New Zealand), and calculates how much each one would have hypothetically paid had they experienced an event similar to the Christchurch (NZ) 2011 earthquake sequence.

Following two major earthquakes in 1931 and 1942, the Earthquake and War Damage Commission was established in 1945. It was established as a State Owned Entity owned by New Zealand Government and managed by a board of commissioners. It became the Earthquake Commission (EQC) in the 1993 EQC Act, the last time the law was revised.

EQCover is the seismic insurance cover provided by the EQC. It provides capped insurance to residential buildings, land and personal contents against the risk of earthquakes, volcanic eruptions, landslips, hydrothermal activity and tsunamis. It only covers residential properties and the land on which they are sited; commercial, industrial, and agricultural properties are excluded from EQCover but are typically covered by private insurers. The EQCover insurance is a de-facto compulsory addendum to standard fire insurance policies (that are typically required by lenders for home loans). Homes without standard fire insurance are not covered by EQCover, but in practice more than 90% of residential properties in New Zealand have it.

The EQCover has strict caps on both structural and contents cover, but anything above the cap has to be insured by the private insurer; the same insurer that issued the fire insurance policy through which the EQCover premiums are collected. Uniquely, EQCover also insures the land beneath the residential properties.[4] The deductible excess is much lower than other international schemes. The EQC buys reinsurance internationally, and also purchases annually a government full 'last resort' guarantee. Any collected premiums that are not used annually are accumulated and transferred to a Natural Disaster Fund (NDF). By 2011, the NDF had accumulated almost $NZ6 billion.

[4] The insured amount is the lower value of either the damaged land's market value or the cost to repair the land to its pre-event condition. This proved to be a contentious issue in cases where the 2011 earthquake caused liquefaction.

In February 2011, a strong and shallow earthquake very close to the Central Business District of Christchurch, New Zealand's second largest city, damaged much of the city. In the aftermath of this event, the cost of reconstruction was very high, and even though the EQC had about $NZ4 billion in re-insurance coverage, it also had to use practically all of the $NZ6 billion that previously accumulated in the NDF over the last few decades.

The EQCover has a flat premium rate irrespective of evaluated risk, and it is significantly more affordable than other international earthquake insurance schemes. Coverage costs 15 cents for every $NZ100 of cover.[5] Maybe not coincidently, New Zealand also has one of the highest take-up rates of residential insurance cover for natural disasters in the world. In the above-mentioned 2011 Christchurch earthquake, practically all residential damages were covered by insurance.

2.4.2 *Japanese Earthquake Reinsurance (JER)*

Japan is the world's most earthquake afflicted country. Following the 1964 Niigata Earthquake[6], the government and general insurance organizations decided to establish an earthquake insurance system. In 1966, Japanese Earthquake Reinsurance (JER) scheme was initiated and the Government of Japan undertook the role of reinsurer for earthquake risk.

JER offers coverage on buildings for residential use and their contents. The JER coverage per insurance policy varies between 30 and 50 per cent of the property value. The claim payment is dependent on the degree of loss. "The Act Concerning Earthquake Insurance" defines the earthquake damage on property

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[5] The cost was tripled from 5 cents after international reinsurers increased their premiums in the aftermath of the 2011 earthquake. It is scheduled to rise again to 20 cents at the end of 2017, as a consequence of another damaging earthquake in November 2016.

[6] The Niigata Earthquake (M 7.5) happened on June 16, 1964, and damaged nine prefectures. The earthquake, ground liquefaction and flooding caused significant damages to infrastructures and residential properties in the region.

and content to three levels: total loss, half loss and partial loss. According to the "Insurance Claim Total Payment Limit", JER system sets the maximum insured amount to ¥JP50 million for residential property and ¥JP10 million for content for a single event. The deductible fee equals the annual premium paid by policyholder with the maximum amount of ¥JP50,000 per policy.

The JER insurance was at first compulsory but has become optional since 1979. Private insurers must enroll in JER scheme if they offer optional earthquake insurance as part of a comprehensive fire insurance policy. The earthquake insurance premiums paid by policyholders are passed-on from the private insurer and managed by the government and the JER system. Both institutions are responsible for reinsurance and providing a limited state guarantee. The maximum liability of the government, JER and private insurance are 87 per cent, 10 per cent and 3 per cent, respectively.

The Tohoku earthquake in 2011 was the costliest earthquake in history. Marsh (2014) reports that the earthquake caused an economics loss of $US210 billion of which only about $US35.7 billion was insured. This devastating disaster wiped out half of the insurance program's reserves (Paudel, 2012b).

JER sets the annual basic premium rate for every ¥JP1,000 of amount insured. The premium rate varies across zones, classified by their seismic exposure and building structures. The premiums paid by homeowners are between 0.05 per cent (risk zone 1 and wooden) and 0.35 per cent (risk zone 4 and non-wooden). The epicenter of 2011 Tohoku earthquake was located in the risk zone 1 which was thought to be associated with the lowest earthquake risk. The penetration rate for the JER scheme is not very high; according to 2015 Japan's Insurance market report, it is increasing but still below 30%.

2.4.3 *California Earthquake Authority (CEA)*

As is true for New Zealand and Japan, California is also very exposed to earthquakes. In 1985, California policymakers required that insurers offer earthquake insurance coverage to dwellings with one- to four-units. The Northridge earthquake of 1994 damaged more than 40,000 buildings and caused losses of $US21.7 billion to insurers. This created a surge in demand for earthquake insurance. However, Roth (1998) maintains that after paying claims and re-evaluating earthquake exposures, private insurers decided to reduce their earthquake risk underwriting and had placed restricting terms on the remaining polices. As a result, the California Earthquake Authority (CEA) was established in 1996.

In California, private insurers now provide earthquake insurance coverage to homeowners by ceding their exposure to the CEA. The CEA provides coverage to both residential structures and content. The scheme allocates 14 per cent of premium revenue to the participating insurers for distributing and administering the policies and handling claims. Insurance companies that do not participate must offer their own earthquake coverage to their customers. About 30 per cent of the collected premium goes toward purchasing reinsurance and other financial risk transfer products. The rest is pooled in a CEA Fund as reserves. The CEA's overall claim-payment capacity is approximately $US12.1 billion. The components of this capacity include CEA accumulated capital ($US5.1 billion), reinsurance ($US4.37 billion), bond revenues and insurer assessments ($US2.6 billion) (CEA, 2016b).

The CEA premium rates are calculated based on the property's construction type, the year it was built, and the earthquake risk for its location (19 different rating zones). The high premium rates and the low collectable claim-payment (deductible excess is often 15% of the claimed amount), makes homeowners reluctant to purchase the CEA coverage. Only 10 per cent of California households have seismic coverage (Marshall, 2017).

2.4.4 The Turkish Catastrophe Insurance Pool (TCIP)

The Turkish Catastrophe Insurance Pool (TCIP) is a compulsory earthquake insurance scheme that, as in all the other previous cases, commenced its operations following the devastating Marmara earthquake in 1999. The TCIP focus is on high-risk urban dwellings as these proved to be very vulnerable in the 1999 catastrophe. The TCIP insurance is mandatory for residential buildings located within municipal boundaries; properties in smaller villages can purchase coverage on a voluntary basis. Households in rural areas who cannot afford insurance are eligible to receive direct financial assistance from the government following a disaster event.

The policy covers dwelling damages with no cover offered for household contents. Similar to the other insurance systems described above, commercial and public buildings are not covered. The sum insured for each claim depends on the construction type (steel, concrete, masonry or others) and the size of the property. The TCIP coverage is capped for dwellings with value over $US83,500 (as of January 2013). More expensive dwellings can typically purchase additional coverage from private insurers.

The General Directorate of Insurance (GDI) of the Turkish Treasury plays the leading role in creating, operating, and implementing changes in the TCIP's policies. A private insurance company manages the program, and is responsible for information systems, claim management and reinsurance. Domestic insurers collect premiums, and take a 17.5 per cent commission. Revenue is also used to purchase international reinsurance. In 2015, the total payment capacity of TCIP, including the available reinsurance, was $US6 billion. The TCIP scheme aims to settle claims within a month and also provide partial fast payment following an earthquake; but this has not yet been tested in a large event (Başbuğ-Erkan, 2007).

The TCIP sets 15 premium tariffs, which are calculated using the level of local earthquake risk (5 zones) and the type of building structure (3 types). The premium rate varies from 0.44 to 5.50 per cent of the insured property value, depending on the seismic resistance and geographic location of the property (Gurenko et al., 2009). There is a 2 per cent deductible fee (of the sum insured) for each claim. The earthquake policy is sold separately from the standard household insurance. Başbuğ-Erkan and Yilmaz (2015) show that there was dramatic increase in the TCIP penetration rate from 4.6 per cent in 2000 to 38.9 per cent in 2015. Regulations are applied to encourage wider participation in the TCIP scheme such as the requirement for TCIP policy documentation to buy/sell a house or to register for water and electricity services.

2.4.5 Multi-national risk pools: CCRIF and PCRAFI

Caribbean Countries (CCs) and Pacific Island Countries (PICs) are both highly exposed and vulnerable to adverse natural events, especially to tropical storms (cyclones/hurricanes) or earthquakes and their associated tsunami risk (Noy, 2016). Both CCs and PICs have very limited financial resilience to catastrophes due to their small size, inadequate building code, limited reinsurance access and borrowing capacity. Lack of economic diversification between countries also makes cross-subsidization for recovery efforts more difficult (especially in the Caribbean, where a single event can easily hit multiple countries). In 2007, the Caribbean Catastrophe Insurance Facility (CCRIF) was established following the collaborative work between the Caribbean Common Market and Community, donor partners and the World Bank. Currently, seventeen out of 20 CCs participate in this multi-national risk pool (CCRIF, 2015).

Following the establishment of CCRIF, the Pacific Catastrophe Risk Assessment and Financing Initiative insurance pilot program (PCRAFI) was launched in 2013. The scheme was managed by the Secretariat of the Pacific Community (SOPAC), supported by the Asian Development Bank and the World Bank, and financed by donor countries (in particular Japan) and the Global Facility for Disaster Reduction and Recovery (GFDRR). Five PICs are currently participating in the insurance component of the program.

The insurance programs in both the Caribbean and the Pacific function as a not-for-profit risk pool facility, providing coverage against earthquakes and cyclones (CCRIF also has a separate program for excess rainfall). In the Caribbean case, a portion of the collected premium is retained in the risk pool as reserves. The rest is used to purchase reinsurance and catastrophe financial derivatives. For instance, according to the World Bank's analysis, CCRIF's claim payment capacity is such that it can pay for a 1-in-1,125 years event – an unusually conservative threshold. Each participating country has its owned attachment point (deductible), and exhaustion point (capped payout).[7]

Both schemes provide parametric coverage. While traditional insurance requires assessments of individual disaster damage, the parametric insurance claim payment in both schemes is based on the estimated (modelled) emergency costs associated with the disaster. Since the parametric coverage does not require on-the-ground inspections, it reduces the insurance cost, makes quick claim payment possible, and provides the affected government liquidity in the disaster's emergency aftermath. For example, Vanuatu received from PCRAFI a claim payment of $US1.9 million less than a month after

[7] For the 2014/2015 policy year, for example, member countries selected attachment point return periods in the range 10-30 years for tropical cyclones; 20-100 years for earthquakes and 5 years for excess rainfall events. CCRIF member countries also selected exhaustion point return periods in the range of 75 - 180 years for tropical cyclones; 100 - 250 years for earthquakes and 25 years for excess rainfall events, with maximum coverage of approximately US$100M currently available for each peril (CCRIF SPC, 2016).

Tropical Cyclone Pam in early 2015. The parametric aspect of these schemes was essentially borrowed from agricultural index insurance.

Parametric insurance also reduces moral hazard because the pay-out only depends on the intensity of the event. The most significant disadvantage of parametric coverage is the possibility of divergence between the incurred damages and the estimated/modelled ones (so-called basis risk). Since the modelling in both these schemes is very conservative, it appears that the most plausible discrepancy is for the model to underestimate the level of damage, rather than to overestimate it (UNESCAP, 2015). For instance, the Solomon Islands government discontinued its participation in the PCRAFI scheme after the modelling did not trigger payments after an earthquake in the Santa Cruz archipelago and floods in the capital of Honiara – the model underestimated the emergency costs associated with the earthquake and the floods were an uncovered hazard (Mahul et al. (2015). Similar examples of recent perceived type II errors in the sovereign insurance pools were the Bahamas in the CCRIF, and Malawi in the African Risk Capacity program.

2.4.6 Private Earthquake Insurance: Indonesia

More than 12 million people live in earthquake-prone areas in Indonesia. The estimated economics exposure to seismic risk is $US79 billion. The Indonesia government established a reinsurance scheme against earthquake exposure in 2003 (PT Asuransi MAIPARK). Its shareholders are 82 non-life insurance and reinsurance companies. MAIPARK functions as a reinsurer and shareholders' clearinghouse for earthquake risk. The Indonesian private scheme sets a benchmark for earthquake insurance pricing. It also invests in public education, research, risk mitigation and risk management activities.

Private insurers offer coverage for agriculture, commercial, industrial and residential properties. The insured objects are comprised of the material damage (building, foundation, stock) and business interruption (gross profit, wages, increase working cost). Earthquake coverage is provided as a voluntary extension of fire policies. The insurance cost is classified based on the property location and its structure type. In 2011-2015, the highest insurance exposure to earthquakes was for commercial policies (41 per cent of total risks), while 47% of the collected premiums were from industrial properties. More than 90 per cent of the incurred claim value in this time period has been allocated to the commercial sector (MAIPARK, 2015).

2.5 The Consequences of Having Insurance

2.5.1 Case Study: The Great East Japan Earthquake (GEJE)

The Tohoku Region was hit by a M9.0 earthquake on 11/3/2011. The resultant tsunami was the main cause of causalities and damages, though the earthquake also led to meltdown of the nuclear reactors in the power plants in Fukushima Prefecture. 88,000 residents were evacuated, with some unlikely to ever be able to return to their homes. The disruption to many manufacturing facilities and supply chains led to slowdowns or stoppages in some production lines and adversely affected manufacturing plants in faraway countries. The electric power shortages due to the stopping of all nuclear power plants in Japan caused difficulties for many industries, and potentially led to a nationwide economic slowdown.

The insurance loss was estimated at $US35.7 billion. Nevertheless, the impact of the catastrophe on insurance companies was limited because of the Japanese Earthquake Insurance mechanism. The total limit of liability the Japanese government assumes, as the reinsurer of JER, is $US54 billion out of a capped liability of $US69 billion for JER. The JER's loss from the GEJE was approximately $US15 billion. There was thus limited impact on the balance-sheets of insurance companies. There is no government support for commercial earthquake insurance coverage. Due to the confidential nature of private insurance deals, it is hard to estimate the effect of the catastrophe on this sector, and we are not aware of (English language) reports describing the performance of this sector in this case.

Based on the lessons from 1995 Kobe earthquake, the General Insurance Association of Japan (GIAJ) had collaborated in efforts to settle claim payments rapidly. Eleven months after the GEJE, JER scheme has settled 99 per cent of reported claims - 885,000 of them (GIAJ, 2012). The JER rapid insurance payments likely allowed local residents to rebuild damaged structures, repurchase necessary living appliances and stimulate production for this demand. We are not aware, however, of any systematic analysis of the impacts of insurance coverage and rapid settlement of claims had on the insured households' and firms' recovery trajectories, their patterns of investment and consumption spending, and their other decisions – for example, whether to stay in the affected area or move elsewhere.

Nagamura (2012) states that the residential insurance take-up rate in the affected regions was approximately 33.6 per cent, which was much higher than the national average of 23.7 per cent because of the local government efforts to encourage it. Overall, and in spite of the higher than typical take-up, no insurance company was made insolvent after the costliest insurance loss in Japanese history.

2.5.2 Case Study: The Christchurch Earthquake Sequence (2010-11)

The September 2010 earthquake caused over 150,000 residential property claims to the public insurer (the EQC) and 5,000 commercial and business interruption claims to private insurers. On 22th February 2011, a M6.3 earthquake struck closer to Christchurch's center, and led to significantly more damage. The Canterbury earthquake sequence was the most devastating catastrophe in New

Zealand's history (Simpson, 2013), and damage was very high (especially relative to the size of the economy). The severe seismic damages resulted in over 500,000 residential insurance claims (buildings, land and contents from 160,000 properties in and around Christchurch) and more than 30,000 commercial and business interruption claims. The number of submitted claims was twice as large as the EQC's expectation of the worst foreseeable event (King et al. 2014).

To stimulate the region's recovery post event, the government decided to require the insurance industry (including the EQC) to offer their customers a repair or rebuild settlement rather than the typical cash payment. The Canterbury Home Repair Program was introduced by EQC and has been operating since 2012.

The process of repairs and the closing of insurance claims have been slow, for numerous technical, legislative, legal, institutional, administrative, and practical reasons. It is not yet finished more than six years after the event. These delays in insurance settlements following the earthquakes have been reported as a major cause anxiety and stress among delay-impacted households. In some cases, residents were unable to live in their partially ruined dwelling but also unable to have it fixed or sell it for extended periods of time (King et al., 2014). The duration and persistence of these negative impacts on residents' psychological wellbeing are largely unknown.

Similarly to residential claims, the commercial insurance claim settlement process also faced significant delays, even though the legal and institutional issues deferring claims were different. As elsewhere, however, the details of commercial claim settlements often remain confidential so research about its impact is much more limited. Based on firm surveys, Stevenson et al. (2011) find that affected organizations financed their recovery primarily by their cash-flow instead of claim payment as these were delayed. A further complicating factor for any speeding of claim resolution and recovery was the cordon placed around the city center for more than two years because of the fear of aftershocks leading to further destruction.[8]

Using the same firm surveys, Poontirakul et al. (2017) find that in the short-term, business survival was not any different between the insured and uninsured firms as payments were paid slowly. In the medium-term, firms which were paid promptly and in full experienced better recovery in term of performance and profitability than those that had incomplete or delayed claim settlements. Interestingly, the latter performed marginally worse than firms that had no insurance.

2.6 Conclusion

To summarize, there is little reason to doubt that a well-designed insurance system is desirable as a tool for disaster risk management. A well-designed scheme should provide financial risk transfer products that are affordable, fairly priced and efficient, with contracts are widely used and penetration rates consequently are high, and that provides an efficient and successful claim settlement process once a catastrophe hit. The potential role for insurance as a risk transfer mechanism was therefore acknowledged and encouraged in the most recent international agreement on disaster risk reduction (the Sendai Agreement signed in March 2015).

Insurance by itself is not a panacea, and only a prudent combination of various financial risk transfer tools and relevant disaster risk reduction measures such as early warning system, risk education and communication, and defensive infrastructure, can minimize disruptions and losses to societies when catastrophic hazards occur (Warner et al., 2013). Insurance, however, can

[8] Businesses were not entitled to full business interruption insurance if their building was located inside the cordon but was unaffected by the earthquakes.

strengthen incentives for some of these other risk mitigating behaviours (Surminski et al., 2016).

Insurance is the most common financial risk transfer tool, but other informal and formal risk sharing arrangements also exist (e.g., mutual (informal) insurance, micro- and macro-contingent loans, catastrophic bonds, and contingent sovereign credit).

These challenges in the supply and demand for insurance are not unique to earthquake insurance. Its markets, however, face additional hurdles as damaging earthquakes are frequently very large-scale events and designing effective processes for the speedy resolution of claims in such large events remains a challenge.

Governments and the international community can and should actively facilitate the dissemination of insurance tools and products through the design of appropriate legal and institutional tools, in conjunction with private insurance entities. Governments should also ensure that the insurance markets that are present operate effectively and indeed deliver on their promises if a triggering event occurs. Much of the details about how these goals can be achieved, however, are not very well understood. There is a real and surprising scarcity of careful research about markets for natural catastrophe insurance.

In any case, it is important to remember that insurance only transfers the financial component of risk. It most certainly does not save lives directly and may only indirectly improve people's wellbeing after catastrophic events. It should therefore only follow important risk reduction measures and mitigation strategies that could and should be prioritized. These measures and strategies can be facilitated and incentivized through insurance markets, but that is another area where both research and policy are still in their infancy.

Chapter 3

Insuring Earthquakes: How Would the Californian and Japanese Insurance Programs Have Fared after the 2011 New Zealand Earthquake?

Abstract

In high-income countries where earthquake risk is perceived to be high, earthquakes are insured if and only if the public sector is involved. The proto-typical examples of this public sector involvement are the public earthquake insurance schemes in California, Japan, and New Zealand. Each of these insurance programs is structured differently, and the purpose of this paper is to examine these differences using a

concrete case-study, the sequence of earthquakes that occurred in Christchurch, New Zealand, in 2011. This event was the most heavily insured earthquake event in history. We examine what would have been the outcome had the system of insurance in Christchurch been different. In particular, we focus on the California Earthquake Authority insurance program, and the Japanese Earthquake Reinsurance scheme. Overall, the aggregate cost of the earthquake to the New Zealand public insurer (the Earthquake Commission) was USD 6.2 billion. If a similar-sized disaster event had occurred in Japan and California, homeowners would have received only around USD 1.6 billion and USD 0.7 billion from the Japanese and Californian schemes, respectively. We further describe the spatial and distributive aspects of these scenarios and discuss some of the policy questions that emerge from this comparison.

3.1 Introduction

Globally, earthquakes can occur almost anywhere, but the risk of earthquakes damaging man-made assets is much higher in some specific regions. This risk is especially acute around the Pacific Rim, the Alpide belt which stretches across the entire Mediterranean from Portugal to Turkey and on to the Himalayas, and the Western edge of Indonesia. Other regions, like some areas in the South Pacific, the Rift Valley in North-Eastern Africa, or the Caribbean can also experience severe events.

In poorer countries, insurance is very rare and is typically purchased only by very wealthy households and larger businesses. In most high-income countries where the risks of earthquakes are relatively low, private insurers routinely include earthquake peril in their coverage. However, in high-income countries where the risk of earthquakes is higher, private insurers are generally very reluctant to offer earthquake cover without substantial government support. The proto-typical examples of this public sector involvement in earthquake insurance markets are the public earthquake insurance schemes in California, Japan, and New Zealand.[9]

Each of these public insurance programs is structured differently, and the purpose of this paper is to examine these differences using a concrete case-study, the sequence of earthquakes that occurred in the Canterbury region around the city of Christchurch in the South Island of New Zealand in 2010-2011. Our aim in comparing these insurance programs quantitatively, a comparison that has not been done before, is to highlight what are the main differences between them. The motivation for this investigation is the growing realization that insurance can play a significant contributing role in the post-disaster recovery process as it has done in Christchurch (King et al., 2014; Poontirakul et al., 2017; Nguyen & Noy, 2018a).

Our case study, the Canterbury earthquake sequence (CES), started in September 2010 with a damaging earthquake centered not far from the port of Lyttleton – a port that serves the city of Christchurch (population about 400,000, the biggest city in the South Island, and the second biggest in New Zealand). However, while there was significant damage from this earthquake, there were very few injuries, and the damage to residential housing was also limited. In February 2011, a strong and shallow aftershock occurred very close to the Central Business District of Christchurch, and damaged much of the city. Tragically, two office buildings collapsed and altogether 185 people died, most of them in these two buildings. Most residential housing in the region experienced some damage, and maybe 90% of the public, commercial and office

[9] Other high-risk high-income regions do not yet have very well-developed earthquake insurance markets (e.g., Oregon and Washington States in the US, British Columbia in Canada, Italy, and Greece). Turkey, a high-middle-income country facing high earthquake risk is unique in developing a large scale publicly-supported insurance scheme. According to the Swiss Re Institute’s statistics, the insured losses from disasters is still well below their total economic losses and this gap is expanding.

buildings in the center of the city were damaged and had to be fixed (or demolished) before they could be occupied again.

The aftermath of the earthquake was challenging for insurers, as it turned out to have been the most heavily insured earthquake event in history, with practically almost all residential housing having insurance, and maybe 75% of commercial properties and office buildings having coverage as well.

Our purpose is to examine what would have been the outcome of the earthquake sequence had the system of insurance in New Zealand (NZ) been different. In particular, we focus on two examples: the publicly-supported earthquake insurance program in California (the California Earthquake Authority), and the public program in Japan (Japanese Earthquake Reinsurance). These are the two most widely known public earthquake insurance schemes[10], and our purpose in this paper is to analyze the deficiencies of both these programs – deficiencies that yield a much lower take-up rates.[11] In so doing, we aim to assist in identifying the potential changes in these programs that can allow policymakers to improve them and therefore potentially improve recovery should another large earthquake occur in these regions (and one inevitably will).

3.2 Earthquake Residential Insurance Schemes

3.2.1 New Zealand Earthquake Commission (EQC)

New Zealand is seismologically very active. On average, there are about 15,000 earthquakes in New Zealand every year, although most are not strong enough to be felt. Following two major earthquakes in 1931 and 1942, the Earthquake and War Damage Commission was established in 1945. It was established as a

[10] A detail comparative analysis between the three insurance schemes are included in table 3-4.

[11] See (Kunreuther & Michel-Kerjan, 2014) for a thorough analysis of hazard insurance programs and the difficulties in providing high coverage. Kusuma et al. (2017) provide an updated review of similar topics.

State Owned Entity owned by the New Zealand Government and managed by a board of commissioners. It became the Earthquake Commission (EQC) in the 1993 EQC Act, the last time the law was revised.

EQCover is the seismic insurance cover provided by the EQC. It provides capped insurance to residential buildings, land and personal contents against the risk of earthquakes, volcanic eruptions, landslips, hydrothermal activity and tsunamis (Fleming et al., 2018).[12] It only covers residential properties and the land on which they are sited; commercial, industrial, and agricultural properties are only covered by private insurers. The EQCover insurance is a de-facto compulsory addendum to standard fire insurance policies (that are typically required by lenders for home loans). Homes without standard fire insurance are not covered by EQCover, but in practice more than 95% of residential properties in New Zealand have it.

The EQCover has strict caps on both structural and contents cover, but anything above the cap is insured by the private insurer; the same insurer that issued the fire insurance policy through which the EQCover premiums are collected. Uniquely, EQCover also insures the land beneath the residential properties.[13] The deductible excess is much lower than other international schemes. The EQC buys reinsurance internationally, and also purchases annually a government 'last resort' guarantee. Any collected premiums that are not used annually are accumulated in a Natural Disaster Fund (NDF). By 2011, the NDF had accumulated almost USD 4.1 billion (RBNZ, 2011). In the remainder of the paper, we convert all the currency figures to USD, based on the 2016 IRS yearly average exchange rate.

[12] Under some specific conditions, the EQC also provides some limited cover for floods and other weather risks (Fleming et al., 2018).

[13] The insured amount is the lower value of either the damaged land's market value or the cost to repair the land to its pre-event condition. This proved to be a contentious liability in cases where the 2011 earthquake caused liquefaction.

In the aftermath of the February 2011 catastrophic earthquake, the cost of reconstruction was forecasted to be very high, and even though the EQC had about USD 3.15 billion in re-insurance coverage, it also had to use practically all of the USD 4.1 billion that previously accumulated in the NDF over the previous few decades (EQC, 2016a).

The EQCover has a flat premium rate irrespective of evaluated risk, and it is significantly more affordable than other international earthquake insurance schemes, including the ones in Japan and California. Coverage costs 0.2 per cent of cover.[14] Maybe not coincidently, New Zealand also has one of the highest take-up rates of residential insurance cover for natural disasters in the world. In the above-mentioned 2011 Christchurch earthquake, practically all residential damages were covered by insurance.

3.2.2 *Japanese Earthquake Reinsurance (JER)*

Following the 1964 Niigata Earthquake[15], in 1966, the Japanese Earthquake Reinsurance (JER) scheme was established by the Government of Japan, which undertook the provision of reinsurance for earthquake risk. The private insurers sell earthquake policies with high deductible fee[16] in the voluntary market and then reinsure their exposure risk 100 per cent with the scheme. JER offers coverage on residential buildings and their contents. The coverage per insurance policy varies between 30 and 50 per cent of the standard fire policy, while the claim payment is dependent on the degree of loss. Legally, the earthquake damage on property and content is classified by three levels: total loss, half loss and partial loss. The maximum insured amount is set to USD

[14] The cost was quadrupled from 0.05 per cent after 2011, when international reinsurers increased their premiums.

[15] The Niigata Earthquake (M 7.5) happened on June 16, 1964, and damaged nine prefectures. The earthquake, ground liquefaction and flooding caused significant damages to infrastructures and residential properties in the region.

[16] The deductible for an earthquake insurance claim equals the annual premium paid by policyholder with a set maximum amount (Paudel, 2012a).

220,000 per residential unit and USD 45,000 for contents for a single earthquake event (JER, 2016).

The JER scheme was at first compulsory but has been made optional in 1979. Private insurers must enroll in the JER scheme which offers optional earthquake insurance as part of a comprehensive fire insurance policy. As in the New Zealand case, the earthquake insurance premiums paid by policyholders are passed-on from the private insurer and managed by the government and the JER system. The maximum liability of the government, JER and private insurance are 87 per cent, 10 per cent and 3 per cent, respectively.

JER sets the annual basic premium rate for every ¥JP 1,000 of amount insured. The premium rate varies across zones, classified by their seismic exposure and building structures. The premiums paid by homeowners are between 0.05 per cent (risk zone 1 and wooden) and 0.35 per cent (risk zone 4 and non-wooden) – compared to 0.2 per cent in the NZ case.

The Tohoku earthquake in 2011 was the costliest earthquake in history. According to EMDAT database, the earthquake caused an economics loss of USD 210 billion of which only about USD 35.7 billion was insured. This devastating disaster wiped out half of the JER program reserves and reduced its capacity significantly. The epicenter of 2011 Tohoku earthquake was located in risk zone 1 which was thought to be associated with the lowest earthquake risk.[17] Even after the 2011 catastrophe, the penetration rate for the JER scheme is not very high; according to 2016 Japan's market report, it is increasing but still below 30 per cent.

[17] This is not unusual. The Christchurch earthquake in New Zealand and the Northridge earthquake in California, both happened in areas that were considered to have relatively lower risk of earthquakes.

3.2.3 *California Earthquake Authority (CEA)*

California is as exposed to earthquakes as New Zealand and Japan are. In 1985, California policymakers required that insurers offer earthquake insurance coverage to dwellings with one- to four-units. The Northridge earthquake of 1994, damaged more than 40,000 buildings, and caused total losses of USD 21.7 billion to insurers[18] (Kunreuther & Michel-Kerjan, 2014). This created a surge in demand for earthquake insurance. However, Kunreuther and Roth (1998) maintain that after paying claims and re-evaluating earthquake exposures, private insurers decided to reduce their earthquake risk underwriting and had placed restricting terms on remaining polices. As a response to these restrictions, the California Earthquake Authority (CEA) was established in 1996 by the state's government.

California now requires private insurers to provide earthquake insurance coverage to homeowners. These companies can either keep their own earthquake risk or cede their exposure to the CEA. The CEA provides coverage to both residential structures and content. The scheme allocates 14 per cent of premium revenue to the participating insurers for distributing and administering the policies and handling claims. Insurance companies that do not participate must offer their own earthquake coverage to their customers. About 30 per cent of the collected premium goes toward purchasing reinsurance and other financial risk transfer products. The rest is pooled in the CEA Fund as reserves. The CEA's overall claim-payment capacity is approximately USD 12.1 billion. The components of this capacity include accumulated capital, reinsurance, bond revenues and insurer assessments (CEA, 2016b).

The CEA premium rates are calculated based on a property's construction type, the year it was built, and the earthquake risk for its location (there are 19

[18] The residential insured losses exceeded $12 billion (Marshall, 2017).

different rating zones). Its high premium rates and the low collectable claim-payment (deductible excess is 15 per cent of the claimed amount), makes homeowners reluctant to purchase CEA coverage (which is voluntary). Marshall (2017) finds that only 10.23 per cent of California households have seismic coverage.

3.3 The EQC claim dataset

We use the EQC claim information pertaining to the Canterbury earthquake sequence (CES) for our analysis. The dataset contains information about every individual claim for earthquake damage in Canterbury region during the CES period.[19] For each claimed event, the EQC data provides the amount paid to claimants or/and spent on repairing damage cost to all three insured exposures (structure, land and content). As set in the Earthquake Commission Act of 1993, the EQC cover is capped at USD 67,000 for building structure, and USD 13,400 for content.[20] The over-cap damage is paid for by the private insurers.[21] EQC assessment team apportioned the total repair cost per property for each exposure and each earthquake event. We use this information as an estimate of the total settlement cost for each property. As each claim is attached to an individual earthquake event (of which there were several in the sequence), we aggregate all the claims for each individual property to obtain the total insurance payment per property. From the EQC records, we can extract the potential amount private insurers would pay for each claim. EQC land cover is the lower value of either the damaged land's value or the repairing cost to its pre-event condition.

[19] The CES started in September 2010. The February 2011 aftershock caused by far the most severe damage, including almost all of the mortality associated with the CES. The last aftershock of the CES was recorded in 2012 (Potter et al., 2015).
[20] The EQC capped payment is NZD 100,000 for building and NZD 20,000 for content.
[21] Private insurers have to compensate a claimant, to restore their damaged property to its "like-new" condition, if the damage cost is over USD 67,000 for each dwelling.

We have data on approximately 230,000 valid CES claims for more than 100,000 properties in the Canterbury region. Three fourths of these claims are for building structure. In this paper, we also use the EQC modelled 2010 value of the exposure, based on the 2010 Quotable Value Property Valuation (QV) and 2013 Census household income for our analysis. We set the maximum potential insurance payment at the exposure value.

Because the EQC caps are applied per dwelling, we adjust the claim payment and exposures' value for the number of dwellings per property. Moreover, to illustrate the data on maps aligned with New Zealand Census data, we aggregate and calculate the average values of the claim variables at the area unit level.[22]

$$Dwelling\ value_{AU} = \sum_{i=1}^{N_{AU}} {(Modelled\ QV_i)}/{N_i} \tag{1}$$

$$Insurance\ payment_{AU} = \sum_{i=1}^{N_{AU}} {\left(\sum_{n=1}^{N} Claim\ payment_n\right)}/{N_i} \tag{2}$$

Where N_{AU} is number of dwelling (i) in each Area Unit (AU) and N is number of earthquake claims (n) for each dwelling. We also compute the average damage ratio of each Area Unit as follow:

$$Damange\ ratio_{AU} = \frac{Damange\ cost_{AU}}{Dwelling\ value_{AU}} \tag{3}$$

3.4 Methodology

In this paper, we estimate how much the impacted homeowner would have received on average if the JER or CEA scheme had been in place to settle the claim payments in Christchurch. To simulate these insurance settlements, we first need to understand overall damage caused by the CES to each dwelling.

[22] Area units are aggregation of meshblocks. They are non–administrative areas that are in between meshblocks and territorial authorities in size. See online appendix figures 2 and 3.

There is a very high penetration rate in New Zealand's residential insurance market; and practically all insurance contracts include earthquake coverage. Almost all CES damage to residential property was therefore covered by EQC and the private insurers. We aggregate the damage on all three residential exposures (structure, land and content) to calculate the overall insurance payments.[23] After the CES, the New Zealand Government defined specific zones as 'red' (no-longer-safe) and bought all residential premises located there; overall about 8000 houses (Nguyen & Noy, 2018b). We assume that these properties were thoroughly damaged and owners received payments equal to their value.

3.4.1 Simulated JER claim payments

We apply the JER claim entitlement, as set in its policy, on the CES residential damage costs to generate what the JER would have paid had New Zealand had a JER-like scheme. The details about the simulation methodology can be found in the online appendix.

Under the Act Concerning Earthquake Insurance, the amount insured is between 30 to 50 per cent. In this case, we assume that all properties that have insurance for structure and contents have coverage that is equivalent to 40 per cent of the insured amount for the standard fire policy (USD 220,000 for building and USD 45,000 for contents). Residential land exposure is not insured by either JER or CEA and is therefore not a JER liability.

According to GIROJ (2014), the amount of JER claim payment is dependent on the earthquake damage-to-value ratio of the insured properties. On average,

[23] In the EQC claim data, the excess fee has been already deducted for each claim settlement. For building structure exposure, if the claim value is NZD 20,000 or less, the excess is NZD 200. If the claim value is higher than NZD 20,000, EQC will pay 99 per cent of it. For content exposure, EQC will deduct an excess of NZD 200 for any amount of the claim. For land exposure, if the claim is less than NZD 5,000, EQC will deduct NZD 500 from the claim payment. If the claim value is above NZD 5,000, EQC will deduct an excess of 10per cent up to the maximum excess amount of NZD 5,000. We add this excess fee for each claim when calculating the earthquake damage per dwelling (EQC, 2012).

impacted residential buildings in Canterbury incurred a loss that is less than 10 per cent of their value. Under the JER settlement method[24], most homeowners would have received only a partial loss payment for building structure (5 per cent of amount insured). Moreover, very few content claims would have been valid because of the restricted policy as set in the JER scheme. The settled amount for claimants would be further lowered when we take into account the private insurers' deductible (excess) fee. The excess of an earthquake claim is the annual premium rate[25] and no more than USD 550 per policy (Paudel, 2012a).

In the Japanese insurance market, both the JER and the cooperative mutual insurers offer coverage against seismic risks. Overall, the Japanese insurers would have only covered 44 percent of CES residential properties in Greater Christchurch under the JER regime.[26] We use this information to generate the average insurance payment for each area unit in the region. Because Japanese prefectures have different penetration rate[27], we conduct sensitivity analysis based on the policy structure and the local take-up rate. Miyagi and Nagasaki prefectures are the regions which have the highest and lowest take-up rates. They are 65.9% and 27.7%, respectively.[28]

3.4.2 Simulated CEA claim payment

Similar to the JER simulation, we use the CEA policy conditions and the actual damages to simulate what would have been the claim settlement in Christchurch under the CEA regime. California's homeowners have various coverage and deductible options with different premiums fee levels. As we do

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[24] MOF (2016) provides a detailed JER claim payment calculation method.

[25] Prior the CES, Canterbury region was considered as medium risk zone. Hence, we apply the JER medium risk zone bracket to calculate the JER premium rate for Canterbury region. The required premium is ¥JP9 (USD 0.08) for ¥JP10,000 (USD 88) of amount insured.

[26] For simplicity, cooperative mutual insurers offer the same insurance policy as the JER scheme.

[27] Some prefectures have higher earthquake risk and insurance premium than others. Hence, the prefecture take-up rates are different accordingly.

[28] These numbers include the non-JER insurance take-up rate.

not have details about the proportional breakdown of these options among those insured by the CEA, we assume all CEA policyholders choose an identical (and generous) policy contract. The insurance payment is capped at USD 200,000. The deductible options vary from 5 per cent to 25 per cent of insured amount.[29]

Given the current take-up rate[30] for residential earthquake insurance in California, we assume that 10.23 per cent residential premises in Canterbury region would have had insurance coverage under CEA regime. In other words, nearly 90 per cent of Canterbury households would have been un-insured for earthquake risk. The 10.23% penetration rate is averaged across high- and low-earthquake risks areas in California. While many homeowners choose not to insure in some regions, certain higher-risk areas[31] have larger numbers of insured households. We undertake sensitivity analysis for different policy options and take-up rate in the next section.

[29] The standard deductible was 15% when the program was established, in the past few years, several additional deductible options where added ranging from 5% to 25%. We assume a 15% deductible (CEA, 2016a).
[30] This penetration rate takes into account both the CEA and the non-CEA participants who offer the residential earthquake insurance in California.
[31] High take-up rate communities are located on the West coast of the state.

3.5 Results

3.5.1 Comparisons of Averages across Insurance Programs

Table 3-1 Summary Statistics for EQC Dataset

	(1)	(2)	(3)
VARIABLES	Mean	St.Dev.	Max
Household income in 2013	47,296	16,661	100,402
Dwelling value	284,402	168,397	1.349e+07
Total estimated CES damage per insured dwelling	44,566	81,345	3,414,513
Total EQC payment per insured dwelling	27,052	38,855	561,522
Hypothetical total JER payment per insured dwelling	7,709	10,014	114,070
Hypothetical total CEA payment per insured dwelling	3,397	5,115	22,699

*All variables are showed in USD

As described in table 3-1, a typical residential dwelling that suffered damages in the CES, incurred a loss that was worth 15 percent of the dwelling value. The EQC payment accounts for only about half the average damage per dwelling. The rest is accounted for by private insurer payments and by the Canterbury Earthquake Recovery Authority (CERA) taking over the damaged properties in the residential red zone.[32] In general, the potential settlement for earthquake damage incurred in the CES with JER and CEA insurance coverage are USD 9,167 and USD 3,920 per dwelling respectively; an amount greatly reduced from the USD 27,052 that was actually paid by the EQC. In other word, the payments under these alternative schemes would have been at most about 18% of the amount that was paid, and 11% of the total CES damages (estimated at USD 44,566 per damaged dwelling).

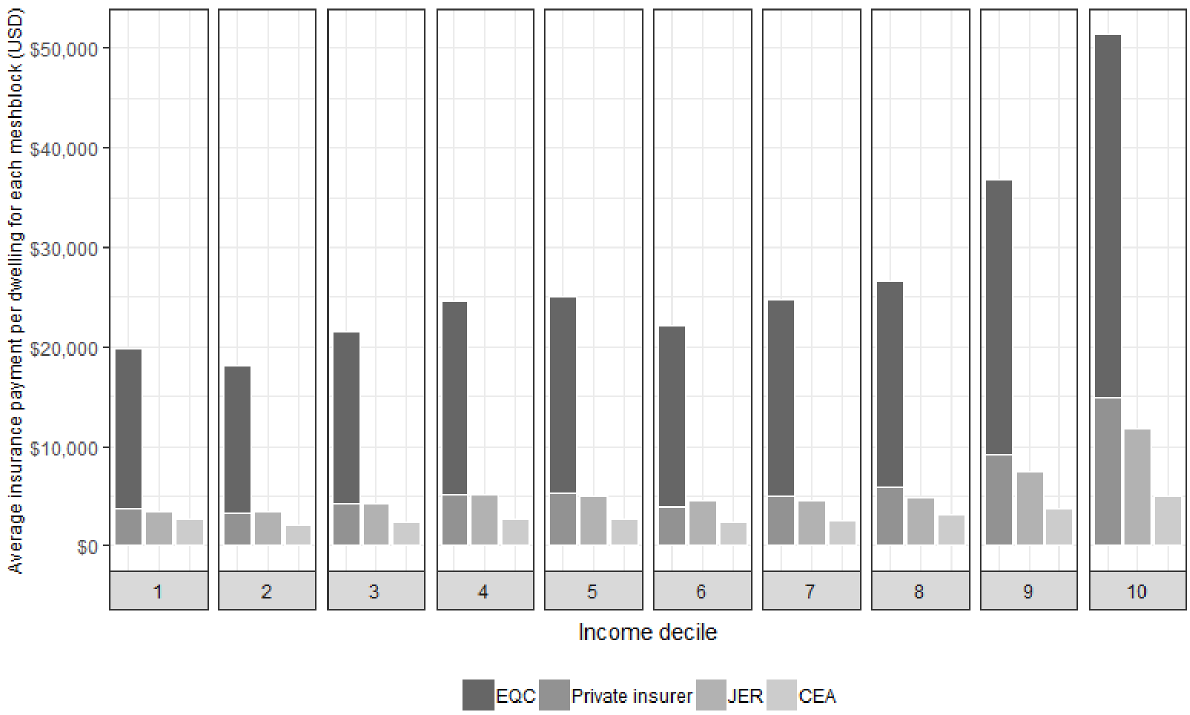
[32] Following the High Court directive in 2015, the Canterbury Earthquake Recovery Authority (CERA) had fully compensated owners of all properties in the residential red zone. We assume that all red zone properties were damaged at their full rateable value. All owners (including uninsured ones) received a payment offer of 100 percent of the 2007/08 rateable value of their land and building structure. The Crown's compensation payment was assumed to represent the private insurer's payment and was considered when calculating the total CES residential cost. As a result, this estimated total cost may be higher than the actual claim settlement by EQC and its private insurers.

3.5.2 Comparisons by Socio-economic Status

As we have detailed data on the claims and their location, we can also match these with socio-economic indicators. In figure 3-1, we graph the actual EQC payments, and the hypothetical JER and CEA payments, for each income decile.[33]

For most deciles (except the top two deciles), the actual insurance claim payment from the EQC and private insurers sum up to USD 15,000 to USD 25,000 per damaged dwelling. The highest income homeowners received payments averaged more than USD 50,000 for their combined public and private claim payment. Unsuprisingly, the richest decile also, on average, settle a much larger share of their claim with their private insurers, compared to other income deciles.

Figure 3-1 Insurance payouts per dwelling by income decile

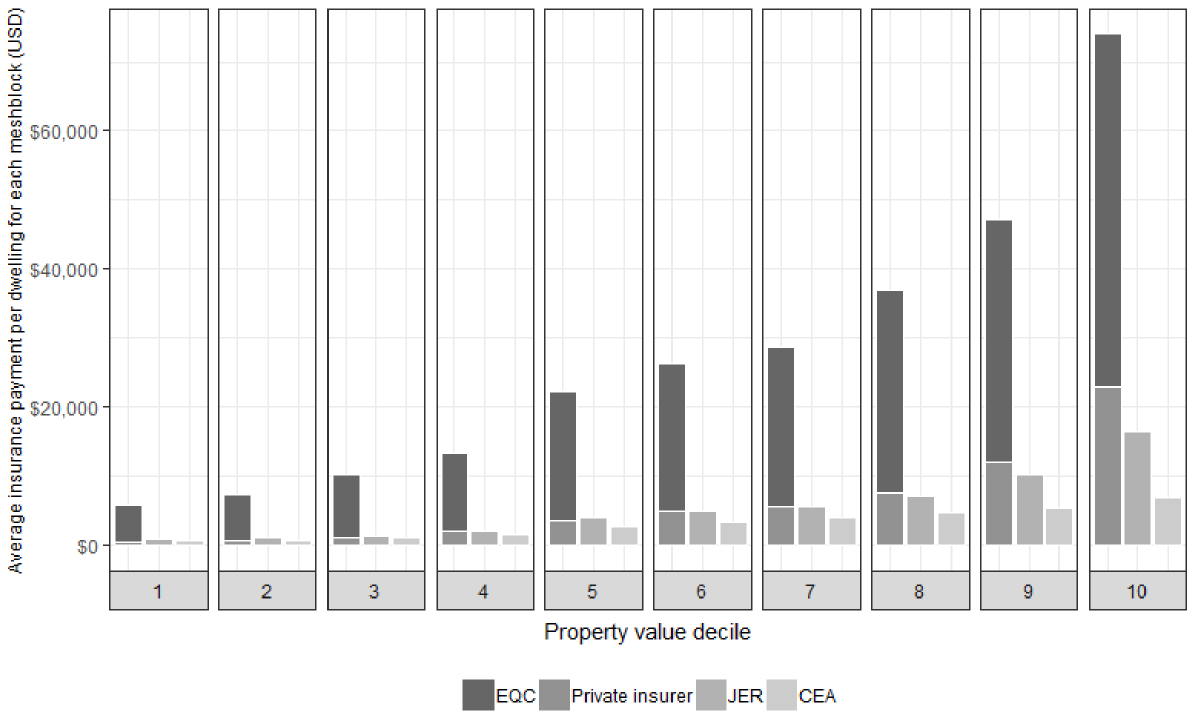


[33] It is important to note that income deciles are identified at the mesh-block level (the smallest geographical unit defined by StatsNZ, contains roughly about 100 people), rather than at the individual level; the insurance claim data does not include the insured party's income information.

Most homeowners that live in high-income mesh-blocks (the top decile) are located in the Port Hills and Fendalton ward. These areas have many expensive residential premises and suffered large loss from the CES. Owen and Noy (2017) also document this finding and provide further information about the ways in which the EQC insurance cover is regressively redistributing money to wealthy (or high-income) owners.

From the simulation, the JER regime would have provided a higher insurance payment than the CEA regime in every income decile. Similar to EQC scheme, the very top decile of highest income earners would have received the highest payout per dwelling under either of the two alternative insurance systems.

Figure 3-2 Insurance payouts per dwelling by property value decile



In figure 3-2, we sort the claims by the insured property assessed value (as provided in the claim dataset for each insured property) rather than by the average income of the insured at the mesh-block level. In this case a one-to-one matching of the property information is possible, rather than at the average mesh-block level, and consequently the data is smoother (and there is no risk of a version of the 'modifiable areal unit problem.'

Similar to figure 3-1, the claim payouts' distribution peaks at the the tenth decile for both EQC and the simulated JER and CEA schemes. We still observe that the JER scheme would have provided more coverage than the CEA. This difference is more pronounced for the extreme upper value properties.

Figure 3-3. Ratio of insurance payouts per property value, by property value decile

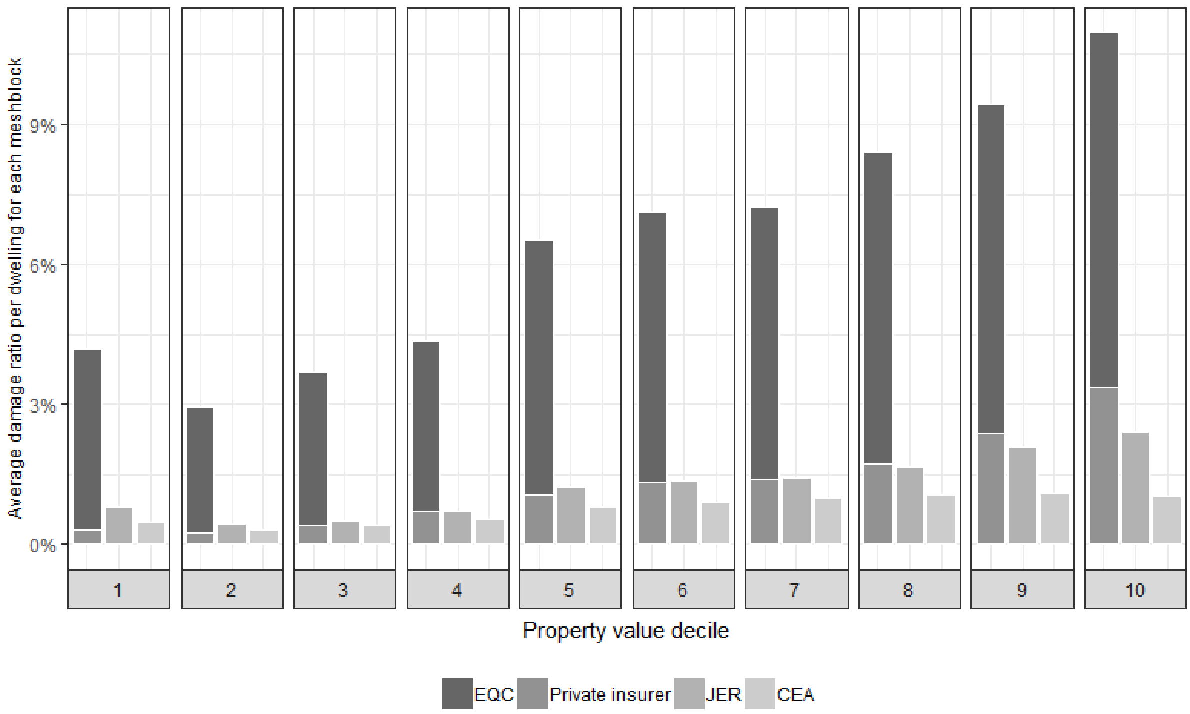


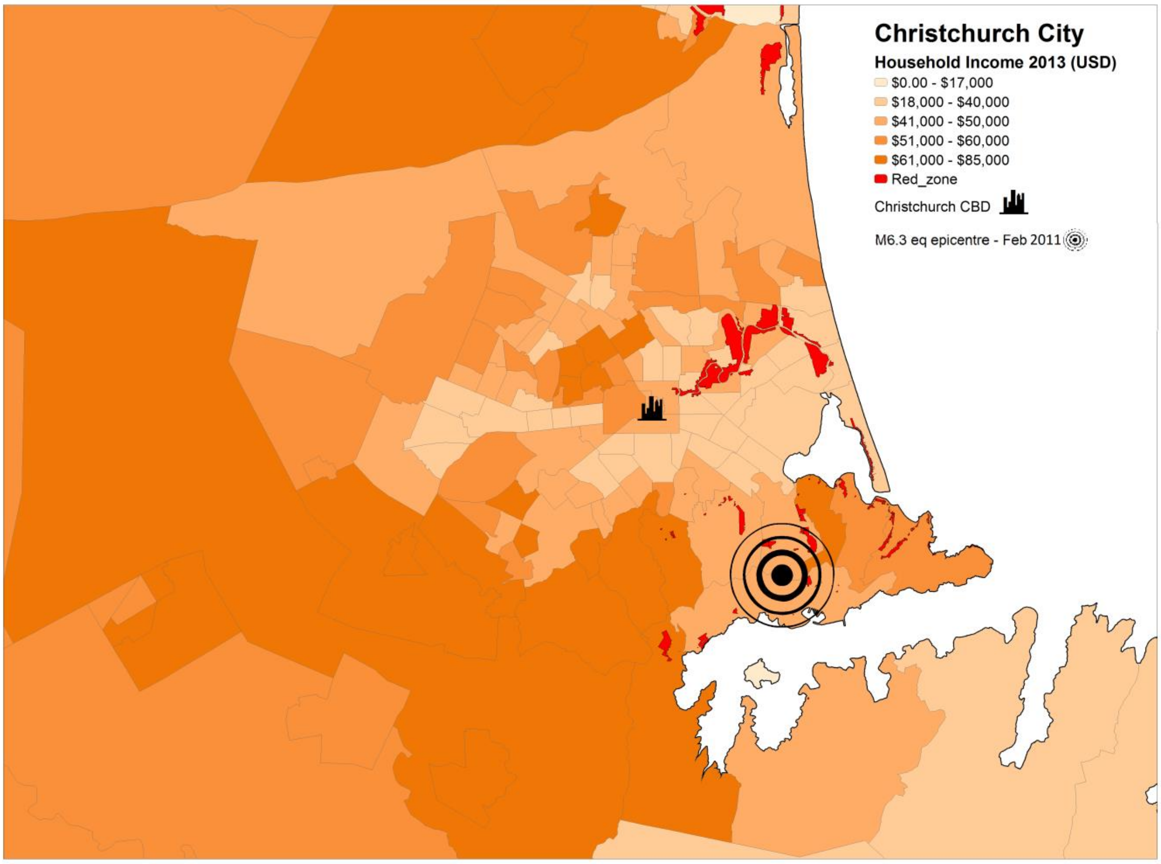
Figure 3-3, like figure 3-2, is constructed using the property value deciles. However, the ratio of insurance payment to property value across dwelling value decile is used on the vertical axis.[34] Some interesting findings emerge, notably that the dwellings in the lowest value decile experienced a higher amount of damage, as a share of their dwelling value, than other low value deciles. The damage ratio is approximately 4.5 per cent for this group, although most of the dwelling claims are still under the EQC cap.

[34] Similarly, the insurance payout to dwelling value ratio across income decile chart is included in the online appendix - Figure 1.

In addition, the damage ratio increases with property value from the second decile. Dwellings in the tenth decile have around a 11 per cent damage ratio. Surprisingly, under the CEA regime, the most expensive properties have a lower payment to value ratio, as compared to the ninth decile, which may indicate that the use of the damage ratio for insurance settlements is a more progressive approach.

3.5.2 Spatial comparisons

Figure 3-4 Average household income (USD) per area unit – 2013 Census



As is true in any city, property prices vary significantly across suburbs. Households who live in the south-western and northern outskirts of the city have higher annual income. The South and Northwest of the central city contain high-income suburbs such as Port Hills and Fendalton (figure 3-4). The East and Northeast of the city are generally the lower average income areas.[35]

The ruptures of the 2011 earthquake went across the Southeast and the South of the city. The damage caused by shakings and liquefaction to these residential premises was considerable. As we already observed, the damaged dwellings in the wealthy areas (the Port Hills and Fendalton) received much higher insurance claim payment than less wealthy household. However, the earthquake damage cost to Fendalton's residential premises is, on average, 10-15 per cent of the property values. The residential premises that received the highest payout-to-value ratio (20-28 per cent), were mainly locate in the Port Hills. Their land claim payment is higher relative to other impacted areas (figure 3-9).

As we previously concluded, if JER were the residential earthquake insurance scheme in New Zealand, only 10 per cent of the damage cost to residential property would be insured (figure 3-10). Unlike the EQC scheme, JER payments are based on the damage-to-value ratio. The payment is also dependent on the sum-insured amount agreed in the policy contract. Moreover, JER policy would not cover the damage the earthquake caused to the land (through, for example, liquefaction). The simulated JER contents claim payment is also much lower than the actual EQC payments for damage to contents. The damage-to-value ratio of insured personal movables is usually very low and the deductible per claim is high. As a result, few content claims would be valid for insurance payment under the JER's conditions.

In our simulation, the CEA scheme would only cover 8 per cent of the destruction costs covered by the EQC insurance system for residential property.

[35] Average household income and residential property values have a positive relationship (correlation coefficient is 0.56). A map of average property values in Greater Christchurch, similar to figure 3-3, has a similar pattern to the household income data (see appendix figure 3-8).

Although the CEA insurance settlement per area unit map have similar pattern to the EQC map, the uninsured residential damage cost under CEA would be much higher. Because CEA does not offer land cover policy, suburbs whose land was highly affected by the 2011 earthquake such as Port Hills, Lyttelton, New Brighton and areas along Avon River would not have land damage compensation. In these areas, the scheme would cover less than USD 13,000 damage cost per household on average so these areas would be very adversely affected (figure 3-11). In fact, homeowners in California are clearly under-insured while having a similar earthquake risk to New Zealand. If the same-sized disaster were to happen in an urban agglomeration in California, a typical (average) household would incur an uninsured loss of over USD 40,000.

We calculate the difference, in each area unit, in claim payment between the EQC and an insurance scheme (*J*= JER or CEA), using the following:

$$diff_{J,AU}^{EQC} = \sum_{i=1}^{N_{AU}} (EQC_i - J_i) / N_i \qquad (1)$$

Alternatively, we calculate the same difference indicator as a ratio of the dwelling value using equation (2):

$$diffratio_{J,AU}^{EQC} = \sum_{i=1}^{N_{AU}} \left(\frac{EQC_i - J_i}{Dwelling\ value_i}\right) / N_i \qquad (2)$$

We then map the area units on a map of the Christchurch area. We present the results of these calculations for equation (2) for the Japanese insurance (figure 3-5) and for California (figure 3-6). The maps for equation (1) area units are available in the appendix (figures 3-12 and 3-13).

The spatial distribution of the 'under-payment' in the case of both the JER and CEA insurance schemes are not that different. Most of the underpayment occurred in the South of the city, and in the East-North-East suburbs. It is surprising that the gap between what the EQC paid and what the CEA and JER would have paid is larger for areas that have higher property values, or that had a lot of damage because of proximity to the epicentre (the South). Maybe more worrying is that a large gap is also evident in the North-East, where average incomes are much lower and there was much damage associated with liquefaction (see figure 3-4).[36]

In these areas of the South and East-North-East, the average gap for all the properties in the area unit's amounts to about 15% of the value of the property. Since, at the time, standard home loans (mortgages) required only a 10% deposit (as they do in other jurisdictions), that gap would have meant that the many households—especially newer ones— would have lost all of their previously accumulated house equity had the insurance regime in New Zealand been more similar to the one in California or Japan.

[36] It is not a coincidence that liquefaction prone areas are also associated with lower income. Liquefaction occurs in area where the water table is high, and flood risk is high, which are in many cities areas where property prices are lower and where the poor live.

Figure 3-5 JER simulation – Difference in claim payments (relative to dwelling value)

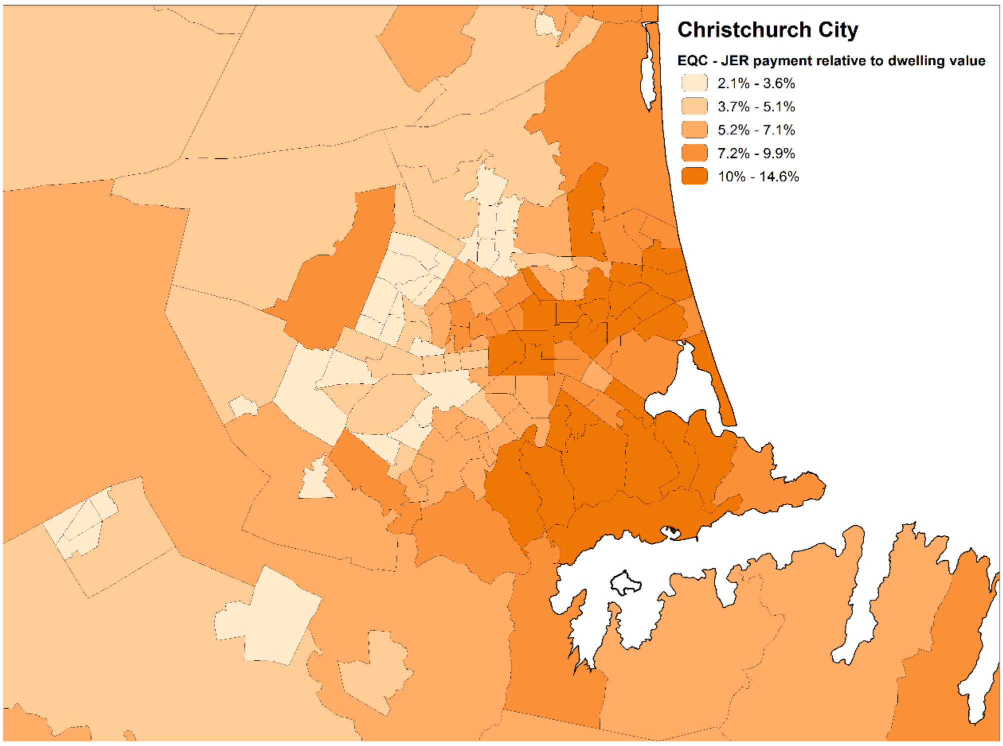
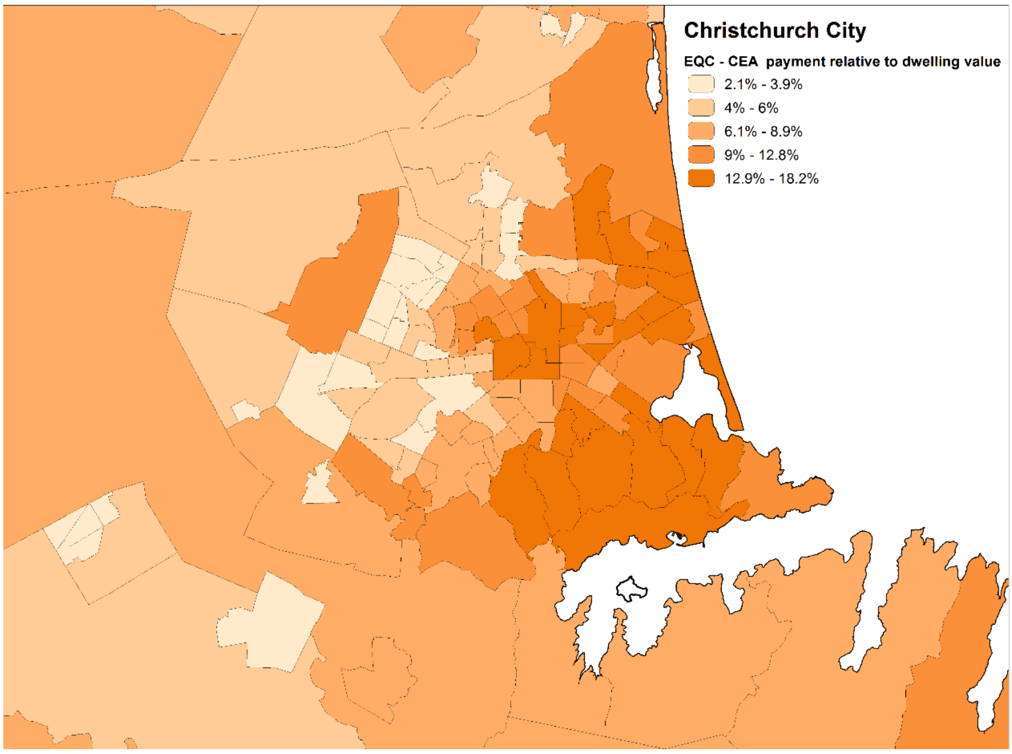


Figure 3-6 CEA simulation – Difference in claim payments (relative to dwelling value)



3.6 Sensitivity analysis

Seismic shocks can occur in any area within Japan or California; yet it is important to note that in all three countries, the most recent catastrophic earthquakes occurred in areas that were considered to have lower risk. In any case, different areas in California and Japan have quite different insurance penetration rates.[37] We therefore conduct sensitivity analysis based on different available policy structures and the range of plausible local take-up rates. In the JER case, Miyagi and Nagasaki prefectures are the regions which have the highest and lowest take-up rates (65.9% and 27.7%, respectively).[38] Similarly, in the CEA case, communities which are located on the coast have much higher penetration rate compared to the inland communities (where earthquake risk is considered lower). The upper and lower bounds of the local take-up rate are 30.6% and 2.4%.[39] The mapped distribution of take-up rate across Japan and California are shown in the online figures 4-14 and 4-15.

In the JER regime, the deductible rate is based on the annual premium. In the sensitivity analysis, we alter the premium rate and premium discount. We also use different sum insured amount and take-up rate to estimate the insurance payment to residential dwelling.

[37] Local insurance take-up can vary because of different perceptions of earthquake risk, different insurance premium, different budgetary constraints, and differences along cultural or institutional dimensions.

[38] These numbers include the non-JER insurance take-up rate which is an additional 14%.

[39] According to California Department of Insurance, the percentage of non-CEA insurers with earthquake coverage is approximately 20% of the market. In our upper- and lower-take up rate, we include the share of the non-CEA insurance.

Table 3-2 JER sensitivity analysis

Scenarios	A		B		C
Sum insured amount	50%		40%		30%
Premium rate*	0.00084		0.00109		0.00165
Premium discount	50%		20%		0%
Take-up rate	64.9%		44%		27.7%
Hypothetical JER payment per insured dwelling (USD)	14,480		7,710		3,640
Total residential insurance cost (USD)	3 billion		1.6 billion		0.7 billion

*Premium rates for scenarios A, B and C are for non-wooden, non-wooden (with retrofit measures) and wooden in medium risk zone bracket (JER, 2016).

Table 3-2 provides us a range of expected residential insurance coverage after a major earthquake shock (similar to the CES) using the Japanese insurance system. Scenario B was used for the analysis in the previous sections. The total cost to the Japanese insurers is expected to be USD 1.6 billion. This cost includes USD 1 billion paid by JER, 0.5 billion by non-JER insurers. And the rest would be divided between non-life insurance companies and the Japanese government.[40] The total insurance amount is bounded between USD 3 and 0.7 billion.

In the CEA case, we apply different indemnity limits for the insured assets. The deductible rate and loss of use payment are also varied. Table 3-3 illustrates the hypothetical CEA dwelling payment and the total cost to earthquake insurers from a major earthquake event. It is worth noting that a number of Californian communities have insurance penetration rate equal to 2.4%; which makes the state unusually underinsured. The total cost of insurance varies in the range of USD 0.1-1.9 billion. In our representative case analyzed in the previous sections

[40] JER (2016) provides a diagram of insurance liabilities, held by JER, non-life insurers and the Japanese government.

(case B), the CEA total payment would be only USD 0.7 billion, given the damage cost to residential property is USD 6.2 billion.

Table 3-3. CEA sensitivity analysis

Scenario	A		B		C
Indemnity limit for structure (USD)	Full		Full		100,000
Indemnity limit for content (USD)	200,000		20,000		5,000
Deductible rate	5%		15%		25%
Loss of Use coverage* (USD)	3,000		1,500		0
Premium discount	20%		10%		0%
Take-up rate	30.6%		10.2%		2.4%
Hypothetical CEA payment per insured dwelling (USD)	11,600		3,397		600
Total residential insurance cost (USD)	1.9 billion		0.7 billion		0.1 billion

*We set an average loss of use coverage for each insured dwelling.

3.7 Why is insurance take-up rate so much lower in California and Japan?

Residential earthquake insurance is not mandatory for homeowners in Japan and California, it is an elective add-on to home insurance policies offered by the private insurance companies as each peril is insured and priced separately. Since the private insurers do not retain (and charge) for any of the seismic risk, they have little incentive to promote its adoption. In New Zealand, the EQC earthquake insurance cover is added, by default, to all residential insurance contracts. This add-on-by-default is perceived by the customers to be mandatory, like a tax, so practically no one chooses not to participate. There is a large literature in behavioral economics that has identified the power of defaults in shaping behavior (e.g., Thaler and Sunstein, 2009). It is clearly the case that some of the difference in take up rates has to do with the way the default option is framed in New Zealand when compared to the other two jurisdictions.

Adverse selection is potentially a problem in voluntary insurance markets such as in Japan and California. Adverse selection leads to equilibria whereby only households that live in high-risk locations decide to obtain insurance coverage. Hence, the premiums collected also have to be high as the risk pool contains mainly high risk households. This makes the cost of insurance very high. Indeed, the premiums in Japan and California are generally higher than in New Zealand – especially in California (see figures 3-14 and 3-15). These high premiums in turn reduce the demand for insurance, further pushing premium prices up as progressively the lower-risk end of the market drops out. Adverse selection is not a current concern in New Zealand, where insurance penetration appears to top 95% in all locations (98% of houses damaged in the Christchurch earthquake were apparently insured[41]).

Another important difference between these markets is that, in New Zealand, there appears to be little expectation from the public that the government will step forward to provide compensatory payments for uninsured houses damaged in a seismic event. Both Japan and the US do have such programs. These programs are small in scale, but it appears that consumers are not aware of the strict limits on the amounts they can receive from these programs. For example, the Federal Emergency Management Agency (FEMA) payments, while available, cannot exceed about US$ 30,000, vastly less than the cost of repairing any significant structural damage to a house in high-cost California.

Households expect government (and private) assistance following a disaster and have therefore weaker incentive to purchase insurance (the 'charity hazard'

[41] This is an estimate, based on the observations that out of the 8000 houses in the Red Zone, fewer than 200 were uninsured; but exact numbers for Christchurch are unknown.

effect). For instance, after the Tohoku earthquake and tsunami, the Japanese government pledged USD 220 billion to help the affected region over five years. In California's case, FEMA provides assistance after any disaster declaration (Raschky & Weck-Hannemann, 2007). In the New Zealand case, the government is quite explicit in stating that it will not assist homeowners that have elected not to purchase insurance – and has maintained that stance in the aftermath of the Canterbury Earthquake Sequence of 2010-2011.[42]

Consumer behavior also affects the demand for insurance. Demand typically depends on past disaster occurrences and losses rather than statistical risk prediction techniques (the 'availability bias'). The take-up rate usually increases after a major disaster, (e.g., post Northridge and Kobe earthquakes). However, this high take-up rate declines quite rapidly and many policyholders drop their coverage within a few years if no new earthquake occurred.[43] Since the EQC covers multiple hazards, its presence is likely to be better known in New Zealand than, for example, is the CEA in California.

One additional behavioral bias that might explain some of the discrepancies in insurance take up rates is the fact that housing is significantly more costly in California than in New Zealand (especially in the coastal region, where most of the state's population resides). A higher house value means that the earthquake insurance premium and home insurance in general, will be more expensive. If people make their insurance purchase decisions based on rules-of-thumb allocations (say, "I will only pay $5000 per year for my insurance, irrespective of how much and what it covers") than it is more likely that homeowners will purchase insurance in lower-price locations. In principle, it is possible to

[42] Except for some instances when it was compelled to assist by the courts (particularly for uninsured Red Zone properties; see Filippova et al., 2018).

[43] The take-up rate for earthquake insurance in Japan has increased by 12 % immediately after the 1995 Kobe earthquake. Similarly, following the Northridge earthquake, the penetration ratio for residential insurance coverage in California reached its peak at 36%, with 22% offered by CEA participants. However, the take-up quickly dropped down and has been bouncing between 10 to 12% since 2000.(Marshall, 2009)

examine this in California – do higher-price locations have lower insurance take-up? – but this investigation is outside the scope of this paper. However, as is shown in the online appendix, the California coast with its higher property values actually has higher take-up rates, rather than lower than the inland areas).

Another important difference is that New Zealand is also characterized by all-perils policies, so buyers are unable to select which risks they choose to cover (and pay for them separately). It is not obvious why insurance in New Zealand is offered only with an all-perils cover, though this probably has to do with both historical reasons and the limited competition that exists in this small market. All perils cover leads to higher penetration rates for low-probability high-impact natural hazard perils like earthquakes (Kunreuther, 2018). In addition, as one of the authors has lived in all three countries, our impression is that the marketing of insurance is much more aggressive and persistent in the New Zealand case, mostly by the banks which also operate as insurance brokers, than it is in Japan or California where that function is separate.

Last, and maybe equally important, is the possibility that insurance is priced 'too low' in New Zealand, and that the New Zealand scheme is therefore not 'actuarily sound.' As we have noted, the earthquake insurance scheme in New Zealand is significantly cheaper, and it might be that the risk is underpriced. However, we note that the current system was set up in New Zealand in 1993, and since then a rare catastrophic event has occurred (in 2011) as well as several other recent unusually costly events (in 2013 in Seddon and in 2015 in Kaikoura), but the scheme has proved to be resilient (and did not need the government lender of last resort guarantee). This suggests, rather, that if anything, the risk in New Zealand is not underpriced, but that the risk in California and Japan might be over-priced. In particular, the New Zealand government is a lender of last resort for the EQC scheme, while, for example, the CEA does not have such an explicit arrangement with the California State government. That therefore means the CEA has to be more conservative in its assessments. We note that an overall actuarial assessment of these schemes is very difficult, as it will largely depend on the estimated likelihood of earthquake events and their costs. The science of earthquake forecasting, alas, is still not precise enough to enable us to have full confidence in such an assessment (see footnote #9).

3.8 Conclusion

The aggregate EQC payments for residential insurance amounted to USD 6.2 billion in its response to the 2010-2011 earthquake sequence (as of 2016).[44] We estimated that the private insurers have paid an additional USD 2.9 billion for the same damage claims for Canterbury homeowners (again, as of 2016). According to our modelling, if a similar-sized disaster event would have occurred in Japan and California, homeowners would have received much less in insurance payments. In the aggregate, JER and CEA would have provided USD 1.6 billion and USD 0.7 billion for the disaster coverage on residential properties, respectively; with some likely range around these two projected figures, as described in section 6. We cannot estimate the payments from commercial insurance for the JER and CEA scenarios, but these would have been much smaller than in the NZ case as well.

The Japanese government warns that the chance of a magnitude M8.0 or above earthquake/tsunami in the Nankai Trough is 70% in the next 30 years.[45] Kawata (2016) estimates that an M9.0 Tokai earthquake would destroy 2.4 million buildings and shut down or seriously damage many important supply chains (e.g., for Toyota, Boeing, Mitsubishi and Yamaha). The estimated losses in the

[44] This figure matches closely with the EQC's 2015-2016 annual report. According to the annual report, as of 30 June 2016, EQC had paid out an aggregate of $NZ 10.8 billion (GST included) (USD 7.2 billion) for damaged residential properties in the CES.
[45] The Nankai Trough is located just below Tokyo and is in the country's industrial centre.

first year would be USD 2 trillion (40% of Japan's GDP) and the Japanese government would have to pay USD 917 billion for recovery (Kawata, 2016). Given the very high gross public debt in the Japan, this may well trigger a financial crisis, with potential adverse repercussions elsewhere.

According to USGS, the likelihood of having one or more M7.0 or above earthquakes in California over the next 30 years is 75%. In California, homeowners can walk away from mortgages without declaring bankruptcy and with no remaining liabilities, so that if a major earthquake occurs, many of the uninsured are likely to abandon their damaged homes and mortgages. This will likely place significant pressure on the US financial system (given California's size), the state and federal governments, and the tax-payers in the affected areas as their localities become insolvent overnight.

In both cases, financial turmoil will likely prolong the post-disaster economic recovery process. Hence, this under-insurance should be an issue of significant concern in both countries, both for locals affected, for taxpayers in the affected regions (as well as at the national level), and for the government at all administrative levels. Given the current financial structure and capacity for both the JER and CEA programs, it is unlikely that they can be expanded significantly without dramatically changing their structure.[46] But, without expanding dramatically, the consequences of a significantly damaging earthquake will have much more adverse consequences than would have been the case with better financial risk transfer mechanisms in place.

It is important to note that it is New Zealand that is unusual in having a high coverage rate. Many other countries exposed to high-impact low-probability hazard events are under- or un-insured. Most notable is maybe Italy, whose earthquake residential insurance penetration rate is lower than 2 percent, in

[46] See (RMS, 2009) for an analysis of expanding coverage for the CEA.

spite of a long history of catastrophic seismic events including most recently the L'Aquila earthquake in 2009.

The aim of this paper was to outline some of the main features that have made the insurance penetration rate in New Zealand so high. This feature of the New Zealand disaster risk management system is widely thought to have contributed substantially to the country's resilience in the aftermath of the sequence of earthquakes it suffered in 2010-2011. One common concern with widespread insurance is that it generates moral hazard; in this case it generates incentives not to protect against earthquake risk by either increasing exposure (the populating of risky areas) and increasing vulnerability (by reducing incentives to build robust housing). There is generally little empirical evidence that supports the view that this is a wide-spread and significant concern in case of earthquakes, as predicting their location is not straightforward, and the presence of insurance does not diminish the incentive to reduce mortality and morbidity from buildings' structural failures.

It is important to note, however, that insurance is not a cure-all for disaster risk, and that even comprehensive insurance systems which cover all asset classes are not sufficient to provide a successful 'build-back-better' recovery. In the New Zealand case, several features of the insurance system actually hindered recovery and potentially changed its trajectory in myriad ways. We would like to especially point out to two issues.

The first has to do with claim processing. When penetration rate is so high (>98%), the speed and efficiency in which claims can be assessed and resolved may be limited. In the case of the Christchurch earthquake, seven and a half years after the earthquakes had occurred (and as these lines are written), a small number of claims have yet to be resolved by both the public insurer (the EQC) and the private ones. This is in stark contrast to the aftermath of the catastrophe in Japan in 2011, where practically all claims were resolved within about two years (Marsh, 2014)

The second concern is that the wordings in insurance contracts have the potential to change incentives during the recovery process. In this case, these incentives may lead to a better outcome for property owners, but a potentially worse outcome to the community and the region's economy. In the case of Christchurch, Kim et al. (2017) found that some features of the insurance contracts led to the demolitions of buildings that could have been fixed and retrofitted, thus delaying recovery and imposing a negative externality on their vicinity.

Both of these disadvantages of high-insurance-penetration, that were exposed in the New Zealand market post-Christchurch, can be directly planned for and countered. So, there is little reason to give up on the first-best, and resort to a second-best scenario in which insurance penetration rates are as low as they currently are in Japan and California.

Appendix - Simulation Methodology

Japanese Earthquake Reinsurance

We use the damage cost and dwelling value, which are available for every insurance claim for the Canterbury Earthquake Sequence (CES), to construct the baseline for this simulation. We apply the 2017 JER policy structure on this data (JER, 2017a). The $Fire\ insured_i$ is the amount of coverage provided by the policy holder's fire insurance. In this simulation, we set $Fire\ insured_i$ equals the dwelling value.

$$Sum\ insured_i\ =\ Fire\ insured_i\ \times 40\% \qquad [1]$$

Where i is an individual insured dwelling. The $Sum\ insured_i$, in Japan, is between 30 - 50% of the fire insurance coverage. In this simulation, we assume the 40% level of fire insured amount. It is capped at USD 460,850 for building and USD 92,170 for content.

$$Damage\ ratio_i = \frac{Damage\ cost_i}{Dwelling\ value_i} \qquad [2]$$

For both building and content exposures, the policy structure is as follow.

$$JER\ payment_i = \begin{cases} 100\%\ of\ Sum\ insured_i;\ if\ Damage\ ratio_i\ \geq 50\%\ \ (Total\ loss) \\ 60\%\ of\ Sum\ insured_i;\ \ if\ 50\% > Damage\ ratio_i\ \geq 40\%\ \ (L-half\ loss) \\ 30\%\ of\ Sum\ insured_i;\ if\ 40\% > Damage\ ratio_i\ \geq 20\%\ (S-half\ loss) \\ 5\%\ of\ Sum\ insured_i;\ if\ Damage\ ratio_i < 20\%\ (Partial\ loss) \end{cases} \qquad [3]$$

$$Deductible_i = Sum\ insured_i\ \times Premium\ rate \times (1 - Discount\ rate) \qquad [4]$$

We have deductible fee equals the annual premium and capped at USD 550. In this simulation, we set the $Premium\ rate$ and the $Discount\ rate$ for insurance premium which are fixed at 0.00109 and 20%, respectively.

$$Net\ JER\ payment_i = \ JER\ payment_i - Deductible\ _i \qquad [5]$$

The average take-up rate of earthquake insurance in Japan is 44%. In other words, in the 'average' community, 44% of the damaged buildings will receive their claim. In our paper, we assume that all claims pay 44% of the amount they are entitled to. We create a hypothetical insurance payment based on this information.

$$Hypothetical\ JER\ payment_i = \ Net\ JER\ payment_i \times Takeup\ rate \qquad [6]$$

California Earthquake Authority

The amount insured in CEA regime is the same as the companion residential insurance policy. We set the cap for indemnity limit to USD 200,000 for building and USD 20,000 for content in this simulation.

$$Net\ CEA\ payment_i = [Damage\ cost_i \times (1 - Deductible\ rate\ )] + Loss\ of\ use \qquad [7]$$

$Deductible\ rate$ is dependent on $Damage\ cost_i$, we keep it fixed at 15%. In this case, we also apply an average $Loss\ of\ use$ (USD 1,500) for each insured dwelling.

Similar to the JER case, we compute the CEA hypothetical insurance payment based on the average CEA take-up rate in California (10.23%) and conduct some sensitivity analysis around that number in section #6.

$$Hypothetical\ CEA\ payment_i = \ Net\ CEA\ payment_i \times Takeup\ rate \qquad [8]$$

Appendix Table

Table 3-4 An overview of residential earthquake insurance in the three countries[47]

Scheme name	CEA (California)	JER (Japan)	EQC (New Zealand)
Year established	1996	1966	1945
Hazard covered	Earthquake and tsunami	Earthquake, volcanic, and tsunami, including fire following such an event	Earthquake, volcanic, landslips, hydrothermal, and tsunami, including fire following such events
Coverage	Residential building and content	Residential building and content	Residential building, content, and land
Compulsory for homeowners?	No	Loosely tied to household fire insurance	Tied by default to household fire insurance
Insurance penetration	9.7%[48]	29.5%[49]	Close to 100%[50]
Premium-setting	Risk based (location, age, construction type, number of storey)	Risk based (location and construction type)	Flat rate
Role of the scheme	Provide insurance coverage, manage reserve fund and in charge of handling claims[51]	Provide insurance coverage, manage the risk reserve and handle claims	Provide insurance coverage, manage natural disaster fund, and handle claims[52]

[47] Currency are converted to USD, based on the 2016 IRS yearly average exchange rate.
[48] Based on the California Department of Insurance 2015 information, residential insurance penetration rate is at 10.23%. The earthquake take-up for non- CEA residential insurers makes up only 0.53% of the whole market.
[49] Japan has a dual residential earthquake insurance system between private non-life insurers - government (JER) and cooperative mutual insurers (JA Kyosai, Zenrosai…). The total penetration is estimated at 44 per cent. The latter group makes up 14 percent of insurance take up in Japan (Mahul & White, 2012; Waldenberger, 2013).
[50] (EQC, 2016a).
[51] CEA is allowed to prorate its claim payment, or to make instalment payments if CEA funds are insufficient.
[52] Under the new EQC reform in 2020, private insurer will be the entry point to resolve claims. This will reduce double handling (EQC and private insurers) and speed up claim settlements.

Private insurers' role	Self-fund the scheme, issue and administer policies, process claims	Sell and administer policies, provide direct cover through the scheme's fund	Sell and administer policies, process insurance claims[53]
Government's role	Facilitate the scheme and promote risk mitigation, risk communication and research	Provide the state guarantee with limited reinsurance and risk mitigation/management	Provide unlimited guarantee, promote risk mitigation, communication, research and education
Liability limit	USD 12.5 billion (5.2 billion CEA capital, 4.8 billion risk transfer products and 2.5 billion post-eq. assessments and debt)[54]	USD 99.87 billion (2.38 billion JER capital, 0.35 billion private insurers and government the rest)[55]	No limit (with the natural disaster fund[56], international reinsurance and the Government's last resort guarantee)
Reinsurance	Different tiers in private market	JER, government and insurers' choice	International reinsurers, government
Deductible per IV[57]	5 - 25%, depend on customer's choice	None[58]	1% for building, USD 134 for contents and 10% for land (USD 335 to 3350)
Annual premium revenue	USD 632.5 million for CEA and USD 352 million for Non-CEA[59]	USD 1.37 billion[60]	USD 188 million[61]

53 Over the EQC's indemnity cap.
54 CEA is the largest CAT bond sponsor among public private partnership insurance schemes. In 2017, the CEA's outstanding CAT bonds were valued at USD 2.1 billion. (CEA, 2016b)
55 (JER, 2016)
56 According to EQC annual reports, the EQC equity balance has been negative since the 2010- 2011 Canterbury earthquakes sequence (CES), and the Natural Disaster Fund is almost exhausted. Hence, if even a medium scale event were to occur in New Zealand in the next several years, it will trigger the government's last resort guarantee.
57 IV is the insured value
58 JER is a public-private partnership reinsurer, deductible fees are only paid to private insurers (Paudel, 2012)
59 (Marshall, 2017)
60 FY2017 Budget - ministry of finance
61 (EQC, 2017b)

Average premium per policy	USD 719 for CEA and USD 1,297 for Non-CEA[62]	USD 199 (USD 133 for building for USD 176,000 of fire coverage and USD 66 for content for USD 90,000 of fire coverage)[63]	USD 185[64] (USD 134[65] for building for USD 67,000 of coverage, USD 37 for contents for USD 13,400 of coverage and no charge for land coverage)[66]
Term insured	One year, short multi-year and longer multi-year	Short-term, one year, two to five years	One year
Amount insured (IV)	Same as the companion residential insurance policy	Up to 50% of insured amount of residential property policy	Replacement sum insured as noted in the fire insurance policy
Indemnity limit	Insured value for building / USD 5,000-200,000 for content	USD 88,00-220,000 for building / USD 45,000 for content	USD 67,000[67] for building / USD 13,400 for contents
Discount rate	5 - 20%	10 - 50%	None
Number of policies	879,537 by CEA and 271,431 by Non-CEA writers[68]	16.8 million policies[69]	1.71 million policies[70]
Scheme's reserve fund	CEA's reserve fund - USD 6 billion[71]	JER's risk reserve – USD 5.55 billion[72]	EQC's natural disaster fund - none[73]

[62] (Marshall, 2017)
[63] (JPC, 2016) JER's premium rate increased 50% from 2014 to 2017
[64] including 15% GST
[65] excluding GST
[66] According to the NZ budget announcement in 2017, EQC levy increases from 15c per NZD 100 to 20c per NZD 100 with an annual cap of NZD 276.
[67] Exclude GST
[68] (Marshall, 2017)
[69] (JER, 2017b)
[70] Based on the EQC estimation, there are 1.71 million dwelling units covered and around 1.65 million contents policies.
[71] (Marshall, 2017)
[72] Before the Great East Japan earthquake (GEJE), the amount of reserves was nearly USD 20 billion at the end of 2010 fiscal year. The earthquake and tsunami wiped out over half of the scheme's reserve. (JER, 2011)
[73] Insurance payments for Canterbury earthquakes sequence and Kaikoura earthquake in 2016 are expected to exhaust all the fund's reserves (USD 4.1 billion), EQC expects to rebuild the fund to USD 1.3 billion in 10 years (EQC, 2017b).

Table 3-5 An overview of insurance exposure history in the three countries

Damage intensity (1990 - 2016)			
	California	Japan	New Zealand
Damage cost:	USD 32.73 billion	USD 400.21 billion	USD 28.4 billion
Insured value:	USD 10.95 billion	USD 47.7 billion	USD 21.1 billion

The information is aggregated based on EM – DAT database (November 2017). The Northridge earthquake hit California in 1994. Its total damage cost is calculated at USD 30 billion and insurance industry paid USD 10.4 billion for the disaster damage. Since the CEA's establishment, there has been USD 500 million out of USD 3.1 billion earthquake damage, covered by insurance sector in California (Paudel, 2012a).

Appendix Figure

Figure 3-7 Insurance payment over dwelling value ratio by property value decile

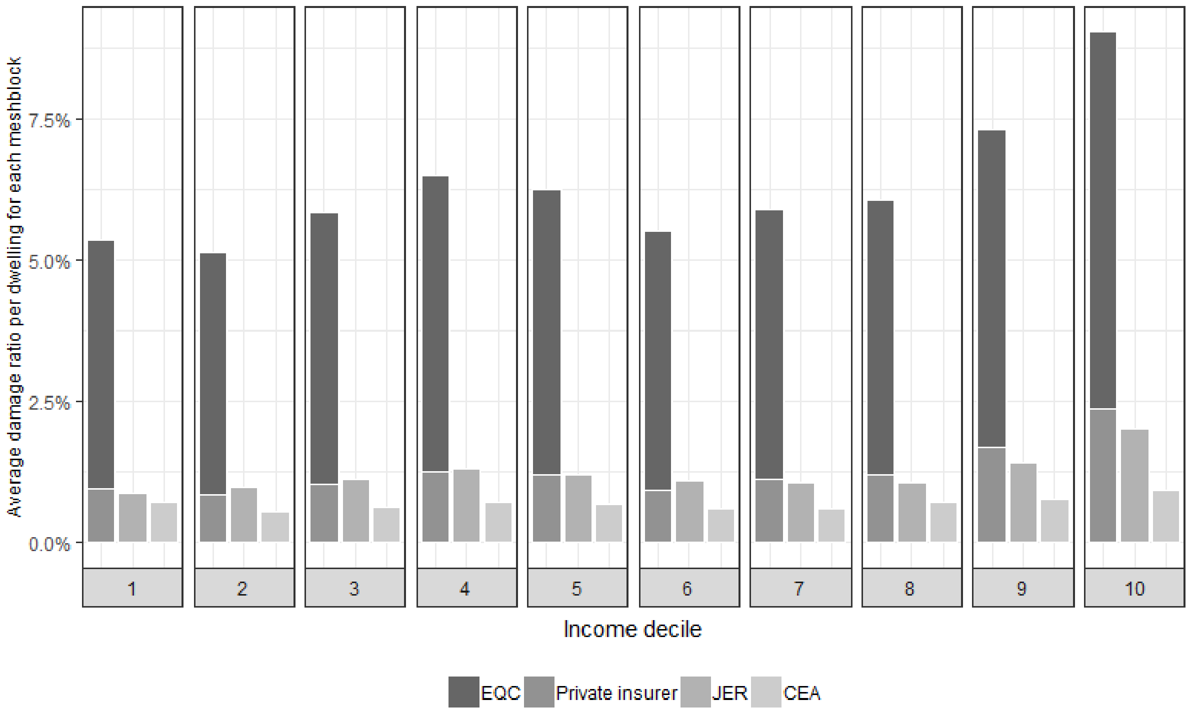


Figure 3-8 Average dwelling value

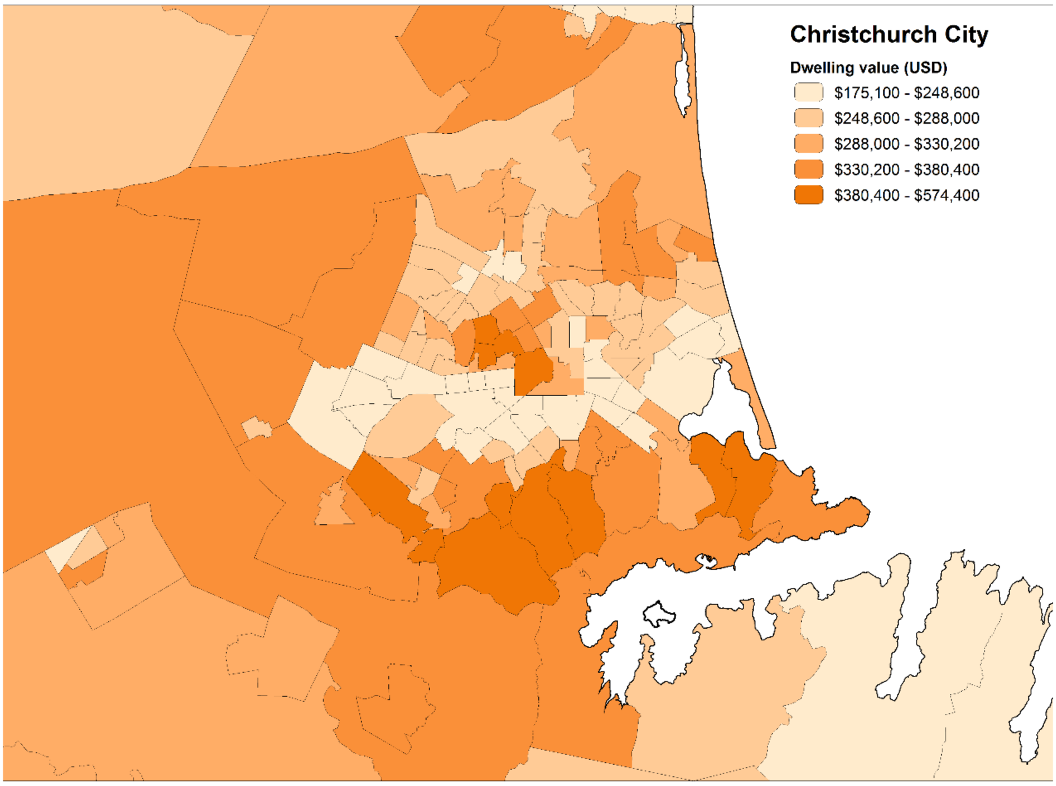


Figure 3-9 EQC claim payment to dwelling value ratio

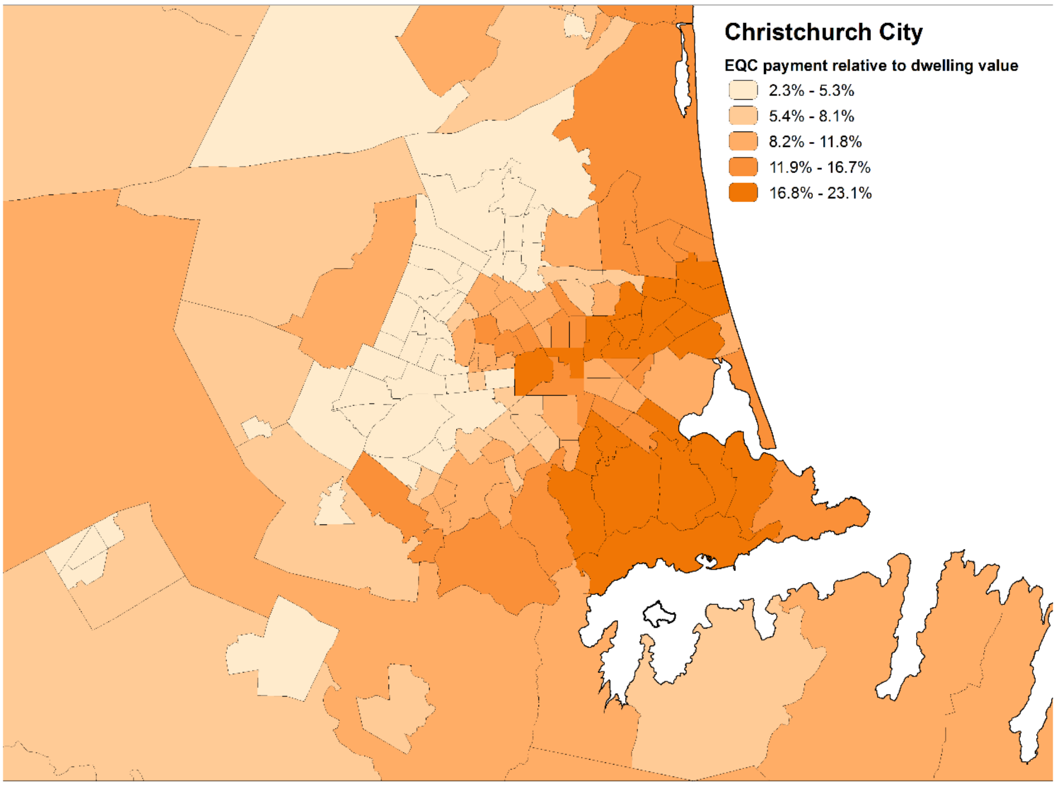


Figure 3-10 JER simulation – Average claim payment per dwelling

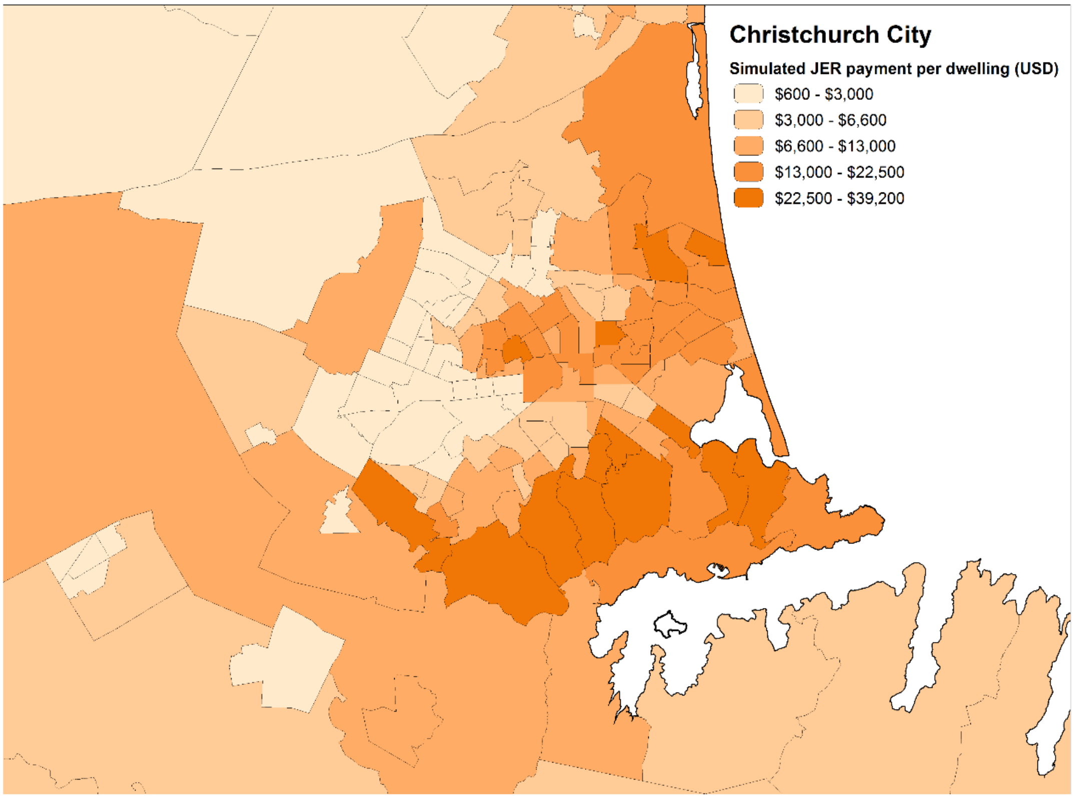


Figure 3-11 CEA simulation – Average claim payment per dwelling

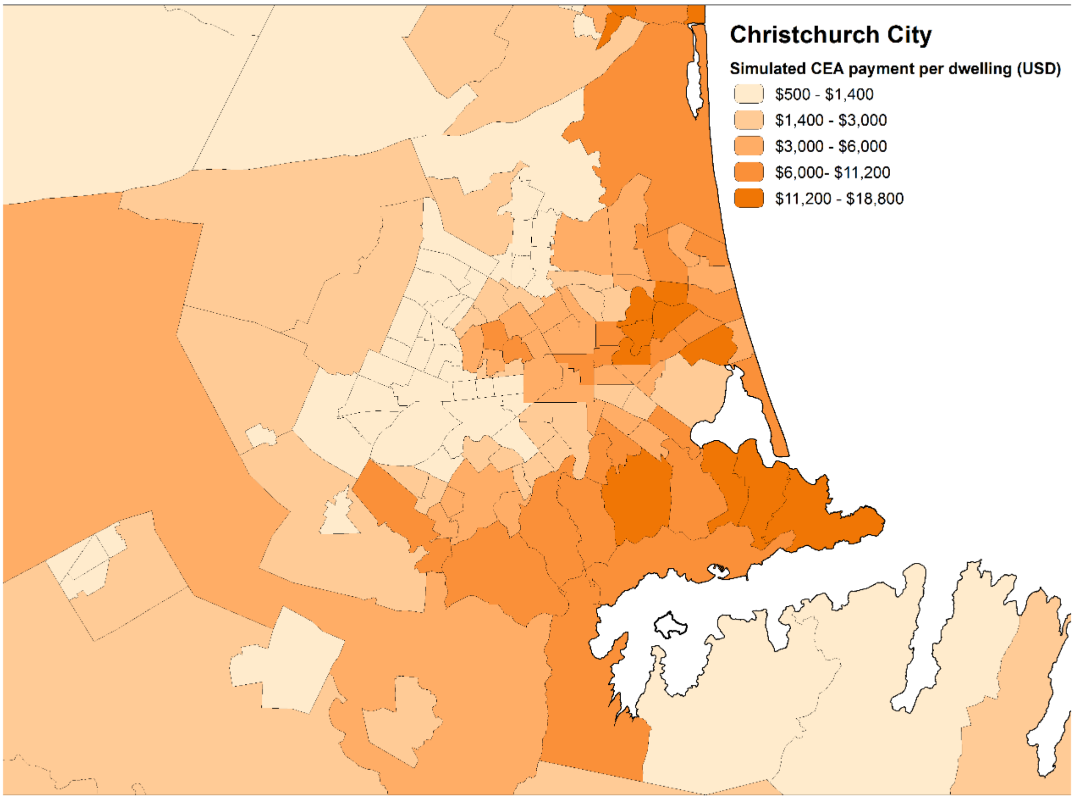


Figure 3-12 JER simulation – Difference in claim payment per dwelling

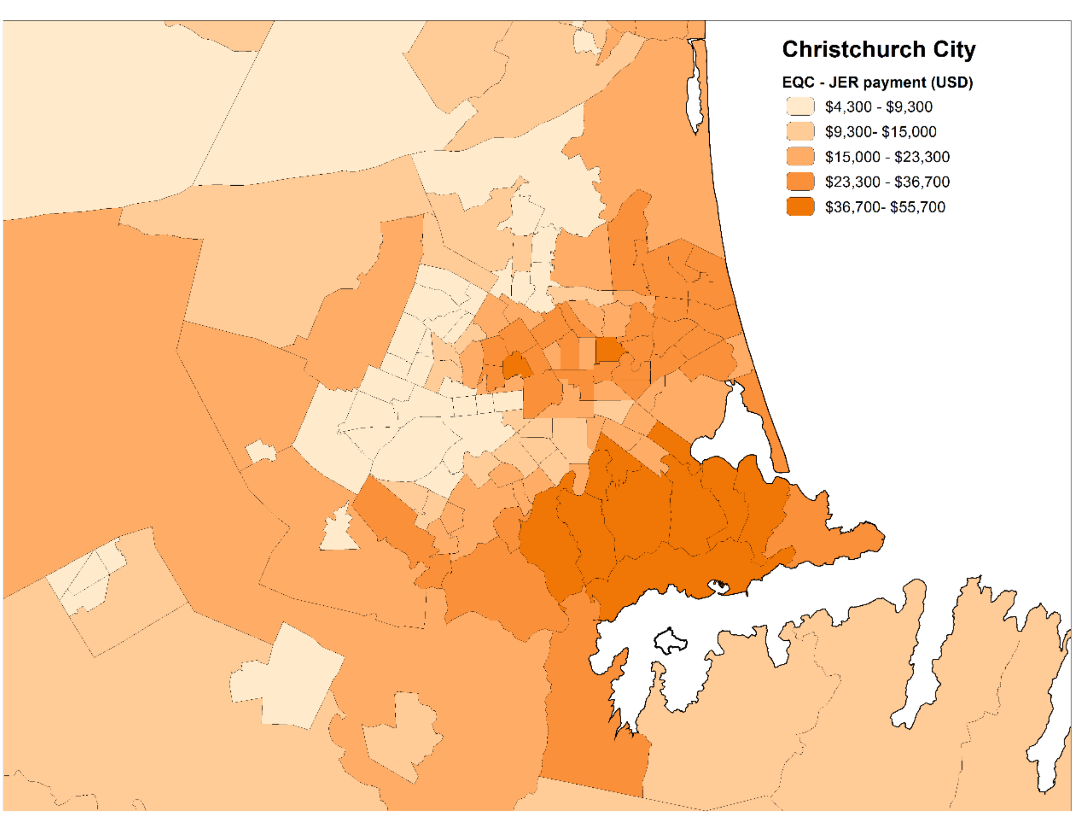
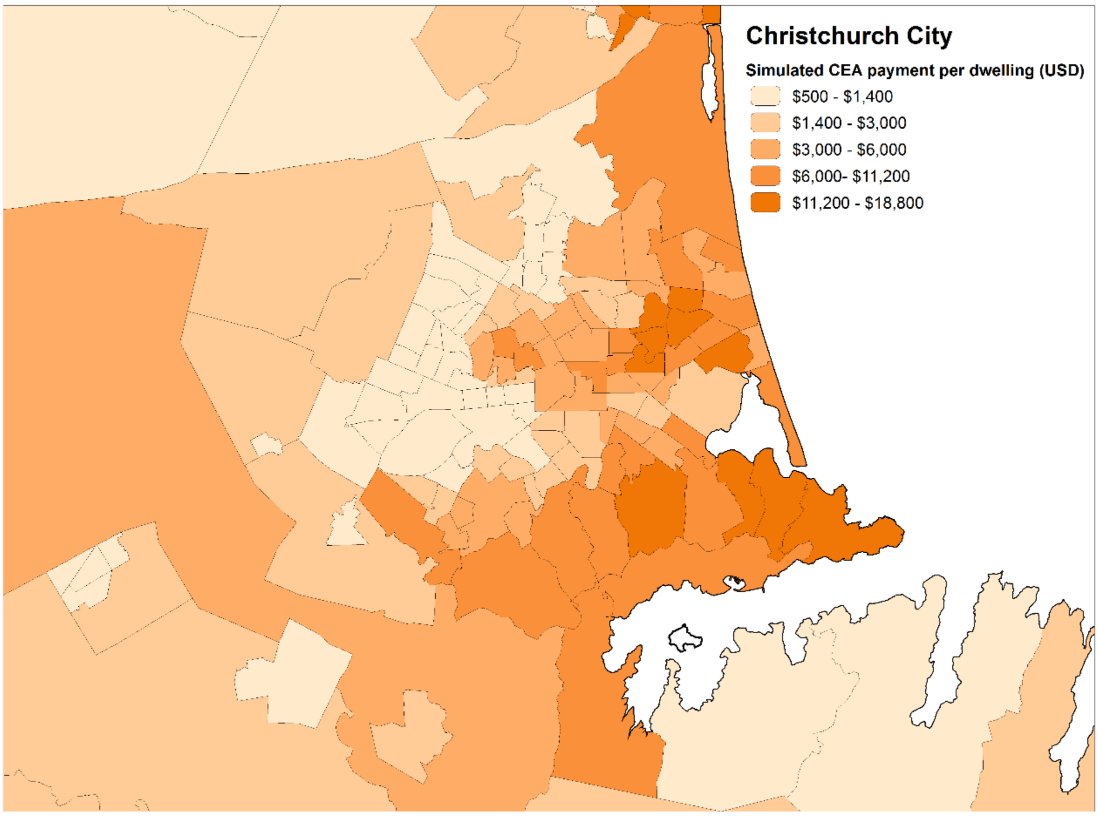


Figure 3-13 CEA simulation – Difference in claim payment per dwelling



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Chapter 4

Measuring the Impact of Insurance on Urban Earthquake Recovery using Nightlights

Abstract

We measure the longer-term effect of a major earthquake on the local economy, using night-time light intensity measured from space, and focus on the role of insurance payments for damaged residential property during the local recovery process. The destructive Canterbury Earthquake Sequence (2010 -2011) is our case study. Uniquely

for this event, more than 95% of residential housing units were covered by insurance and almost all incurred some damage. However, insurance payments were staggered over 5 years, enabling us to identify their local impact. We find that night-time luminosity can capture the process of recovery; and that insurance payments contributed significantly to the process of local economic recovery after the earthquake. Yet, delayed payments were less affective in assisting recovery and cash settlements of claims were more effective than insurance-managed repairs.

4.1 Introduction

New Zealand is prone to earthquakes. Recent destructive earthquakes in 2010, 2011, 2013 and 2016 have demonstrated the seriousness of this risk, and have shown that the local recovery from such events is often not easy. In recent years, numerous papers have looked into the immediate restoration from disasters, often from a microeconomic, single household, perspective, or by focusing on a specific case-study (Rose et al., 1997; Sawada & Shimizutani, 2008; Chang, 2010; duPont Iv et al., 2015; Cole et al., 2017). However, the absence of detailed and sufficiently frequent microeconomic data has hindered attempts to shed more light on the dynamics of recovery over time except for at the macroeconomic national level.

Moreover, the insurance sector is often thought to play a significant role in recovery post-disaster, but analysis of its precise functioning during the recovery process is rarely if ever pursued. Insurance is frequently mentioned as (almost) a panacea for disaster risk, and it is singled out as an important part of international disaster risk reduction efforts as specified in the United Nation's 2015 Sendai Framework for Disaster Risk Reduction and the InsuResilience initiative launched by the G20 in 2017 with the promise of generous funding and ambitious goals. Yet, except for Von Peter et al. (2012) and Poontirakul et al. (2017), there is no research that attempts to look into the role of insurance payments in post-catastrophe recovery.

Our aim here is to provide a first attempt at measurement of the longer-term economic effect of insurance payments after a major earthquake event, using satellite night-time light intensity as a proxy measure for economic activity. Put differently, we investigate how insurance claim payments for damaged residential property, and specifically their timing and type, affect the recovery process of the local economy.

We focus on the destructive Canterbury Earthquake Sequence (CES) in 2010 - 2011 as our case study. We chose this event due to the availability of the insurance claim payment data, and specific characteristics of the earthquake and the insurance market in New Zealand that allow us to identify the impact of insurance payments. These are detailed in the next section.

Our main findings suggest that the night-time luminosity can capture the earthquake damage and the process of recovery. We find that the insurance pay-out contributed significantly to the process of economic recovery after the earthquake; and further identify the importance of the timing of payments, and the relative efficacy of cash payments versus insurance-managed repair.

This earthquake sequence is an attractive case study for several reasons: First, the event is unique as more than 95% of residential housing units were covered by insurance, and practically all submitted a claim. Thus, unlike almost all other disasters where insurance penetration rates are much lower, there is no problem of selection bias (i.e., households that purchase insurance are different from those that do not). Second, these were really big events, from an insurance perspective. Two of five earthquakes in this sequence are listed as some of the costliest insured events, globally, ever. Several geographic aspects of Christchurch make it especially feasible to conduct the analysis we do using night-time luminosity – especially noteworthy are the fact that the city is composed of mostly low rise, spread out residential neighborhoods (so that the nightlight sensors are not overwhelmed with intense light) and there are many nights of low or no cloud cover (making the measurements more consistent throughout the year).

We first verify that the reduction in the night-time light intensity between 2009 and 2011 can be used to estimate the immediate direct impact of the earthquakes on local economic activity, using the insurance claim payment data as a direct earthquake damage indicator. In our primary estimations, we explore the role these payments played in the recovery trajectory in the medium run. We use the quarterly change in the nightlight radiance values, which were observed between 2012 and 2016, as the dependent variable – as a proxy for economic recovery.

The remainder of this paper is structured as follows. In the next section we provide information about the earthquake events, earthquake insurance in New Zealand, and the recovery process. We next discuss the use of nightlight luminosity as a proxy for economic activity and the history of its use in the analysis of disaster impact and recovery. After covering these literatures, we describe the data and methodology used in this paper. In the penultimate section, we present our empirical results; and we end with some further comments about future research.

4.2 The Canterbury Earthquake Sequence 2010 - 2011

On 4th September 2010, a M7.1 earthquake occurred epi-centered close to Darfield village, a rural area not far from the city of Christchurch (the biggest city in the South Island of New Zealand, with a population of about 400,000). The earthquake damaged nearby towns and the eastern suburbs of the city which were vulnerable to liquefaction. Many old unreinforced masonry and heritage buildings were affected as well. This event was followed by a shallower M6.3 aftershock to the southeast of the city on 22th February 2011. This event resulted in intense fault motions which were directed toward the city center (GeoNet, 2011). Many buildings in the Central Business District (CBD) and elsewhere in the city were severely damaged.

There were 185 fatalities in the February 2011 earthquake.[74] Practically all residential buildings in the city experienced at least some damage, with many thousands eventually requiring complete rebuilds. Some areas around the Avon River, that goes through the CBD (from West to East), suffered heavily from subsidence. The flood and liquefaction risk of this area was eventually found to be unacceptably high, and the government decided to re-zone it for non-residential use and bought the homes from their owners (a total of around 8,000 residential properties were defined as residential red zones). Following all this, there were numerous aftershocks in 2011-2012, which mostly led to additional destruction to previously damaged buildings, and to delays in reconstruction.

This Canterbury Earthquake Sequence (CES) was the most devastating catastrophe in New Zealand's modern history (Simpson, 2013). New Zealand has a very high insurance penetration ratio, with more than 95% of residences being insured for earthquakes (Nguyen & Noy, 2019).[75]

The New Zealand Earthquake Commission (EQC) is a public entity providing the first layer of residential insurance cover for earthquakes. The EQC was liable for residential claims that cover dwelling damage up to USD 67,000,

[74] The majority of people were killed because of the collapse of two office buildings – the Canterbury Television (CTV) building, constructed in 1992, and the 1963 Pune Gould Corporation (PGC) building. Almost all the other deaths occurred when façades of both old and modern commercial buildings in the CBD collapsed.

[75] Nguyen and Noy (2019) emphasize the uniqueness of New Zealand's earthquake insurance in term of the high penetration rate and the extent of coverage by comparing it with other international insurance schemes.

content damage up to USD 13,400, and some land damage.[76] [77] The residential over-cap (over the EQC cap) and out-of-scope claims for damages (for example to driveways or fences) were handled by the private insurers. Based on the EQC data we analyze in this paper, approximately 25,600 residential building over-cap claims were transferred to private insurers to be resolved. EQC (2017a) reports that the public insurance scheme has settled over 167,000 and 73,000 valid dwelling and land claims, respectively. These claim settlements would cost the public scheme approximately USD 7.2 billion (EQC, 2016b).

The number of submitted claims was twice as large as the EQC planned for from a 'worst foreseeable event.' Private insurance companies also had limited experience handling such a large number of claims prior to this event, and almost no experience coordinating their work with the EQC. Further complications were the large number of aftershocks spread all over the city, many previously unacknowledged ambiguities in insurance contracts, complex cover for land damage that is not available in other jurisdictions, and a legal system that was also overwhelmed post-earthquake. These complications led to an insurance settlement process that has taken over seven years to complete, and as of this writing (end of 2018) there are still some claims being settled. These delays in claim settlements, whose spatial distribution appear to be random, allow us to identify the effect of insurance payments on recovery.[78]

Our study is the first empirical work, as far as we know, that investigates the role of insurance claim settlement on local recovery, by exploiting the variations

[76] Liability for land damage is capped at the market value of the land. The local currency cap amounts are NZD 100,000 for dwelling damage, and NZD 20,000 for contents. These nominal caps were set in the1993 Act.

[77] In the remainder of the paper, we convert all the currency figures to USD, based on the 2016 IRS yearly average exchange rate.

[78] The ongoing seismicity afflicted the whole city (as each aftershock was epicentered in a different part of the city. There is also no evidence of any spatial pattern in the decision-making by homeowners (a significant cause for delays). We show the full timing profile of quarterly payments in a stop-motion clip of maps, posted here.

in the timing of the insurance payments. We rely on the availability of a proxy measure for recovery (night-time luminosity) in both the spatial and temporal detail that are required for accurate identification of the recovery patterns.

Three other aspects of the insurance system in Christchurch are helpful in establishing the identification of the causal channel from insurance payments (based on their timing) to recovery: (1) Almost everyone had residential insurance in Christchurch; no one knows the exact number of uninsured properties, but from the Residential Red Zone properties for which we do have data, and which we view as a random sample of 8000 residential properties, the insurance penetration rate was about 98%. (2) Almost all properties incurred some damage, even if minor, and the excess (deductible) in the EQC contract was very low. Given these observations, almost everyone made a claim to the public insurer in Christchurch (and therefore there is no selection issue). (3) Earthquake risk was considered very low in Christchurch; in the pre-2010-11 New Zealand Government's seismic risk zone maps (these determine the benchmark for building standards), Christchurch City was viewed as low risk (out of three levels, it had the lowest risk level). We therefore do not expect that seismic preparedness was undertaken at all by the vast majority of households so that damages were not endogenous to the characteristics of the households/owners.

Several other research projects have looked at the CES and it is worthwhile to briefly describe their findings as they pertain to our focus on residential areas' recovery. Similar to residential properties, commercial insurance claim settlement also faced delays due to the scale of claim handling, the complexity of claims, the ongoing seismicity, and the lack of experienced loss assessors. Additional reasons for delay in the assessment process include poor information management, slow decision-making by claimants and the use of brokers for claims settlement (Brown et al., 2013; Seville et al., 2014; Brown et al., 2016a). Using surveys, Stevenson et al (2011) found that affected organizations financed their recovery primarily with their organizational cash-flow instead of from the proceeds of their claim payments. With these same surveys, Poontirakul et al. (2017) find no short-run difference in likelihood of business survival between insured and uninsured firms. However, later on, firms which had prompt and full claim payment experienced better recovery - in terms of performance and profitability - than those that had insufficient cover or delayed claim settlements; and the latter firms performed marginally worse than uninsured firms.

4.3 Insurance and Disaster Recovery Elsewhere

The literature on the economics of disasters has grown significantly in recent years, especially in its investigation of the varied immediate impacts of disasters. Yet, relatively less is known about the post-disaster recovery process and the factors that shape it – see Noy and duPont (2018) for a survey of the existing literature. Very few papers have closely looked at the role of insurance post disaster. The research community has largely focused on explaining insurance penetration, while the insurance companies' research has concentrated more on estimating expected disaster loss and their liabilities than on measuring their role in the recovery process (Kusuma et al., 2017). Melecky and Raddatz (2015) find that high- and middle- income countries, which have high insurance penetration, are affected less and experience better economic recovery following a disaster; and similar findings are reported in Von Peter et al. (2012) – both use aggregate country level data.

Platt et al. (2016) describe the use of a wide range of data sources to identify the speed and the quality of recovery after major earthquakes. These sources include satellite imagery, crowd-sourced geographic information, ground surveys, household surveys, official publications and statistics, and insurance data. They conclude that remote sensing seems to provide accurate and reliable information.

4.4 Night-time Luminosity in Economic Research

In the past decade, night-time light has been increasingly used in the social science literature as an indicator for economic activity and human development. Because most consumption and household activities require illumination in the evening, using changes in light intensity as a proxy for GDP per capita growth appears to be feasible. When household income increases, its light usage also increases (i.e., lighting is a normal good). Studies showing the relationship between night-time luminosity and socioeconomic information are numerous (Sutton & Costanza, 2002; Doll et al., 2006; Sutton et al., 2007; Elvidge et al., 2009a; Ghosh et al., 2009; Ghosh et al., 2010; Chen & Nordhaus, 2011; Kulkarni et al., 2011; Michalopoulos & Papaioannou, 2013; Hodler & Raschky, 2014a; Pinkovskiy & Sala-i-Martin, 2016).[79] In all these, night-time illumination data is obtained from DMSP/OLS or VIIRS DNB satellites.[80]

Luminosity data is used with spatial detail that is never available from statistical agencies. It has been used to measure income at the sub-national level at various grid-cell sizes (Besley & Reynal-Querol, 2014; Montalvo & Reynal-Querol 2016; Storeygard, 2016; Bruederle & Hodler, 2017; Henderson et al., 2018), projected onto cities and municipal boundaries (Brown et al., 2016b), and

[79] Using panel data of over 100 middle- and low- income countries, Henderson et al. (2012) argue that the elasticity of change in night-time lights with respect to income growth is close to one, but this unit elasticity is obtained after the authors have used night-time lights to adjusted GDP for all countries for which they deem GDP data to be of limited quality. Their reported elasticity for the unadjusted country GDP data is around 0.35 which is similar to the findings in other sources (e.g., Storeygard (2016)). Bickenbach et al. (2016) claim that the elasticity of regional GDP with respect to night light tends to be unstable for both developed and developing countries.

[80] See the data appendix for more detail about the luminosity data.

for administrative regions (Hodler & Raschky, 2014a, 2014b; Bickenbach et al., 2016). The correlation between the night-time light and economic activity tends to be weaker at very small unit levels (e.g., one pixel), so some aggregation is necessary. For example, Mellander et al. (2015) find that night-time light at fine spatial level is a better proxy for night-time population than day-time business activity or total wage incomes. These authors also confirm that light (in levels) is a better within-country indicator of urbanization, as it captures population density.

Some have used night-time light in order to investigate the economic losses and recovery post disaster event. For instance, Klomp (2016) explores how large-scale disasters affect economic activity, using night-time light intensity and historic data on 1000 natural hazard events between 1992 and 2008. He finds that geophysical and meteorological events reduce night-time illumination in developed countries while hydrological and climatic disasters lead to a short-term decline in the light intensity in developing countries, and that earthquakes have prolonged negative effects. On average, an event can cause damages that are roughly 2.5 times larger than losses from the major drought and flood.[81] Similar findings, using geo-coded indicators of disaster intensity, are reported by Felbermayr et al. (2018). Gillespie et al. (2014) use household survey data (2004-2007) in Sumatra during the recovery from its 2004 earthquake/tsunami to reveal the link between night-time luminosity and spending per capita at the community level, and Skoufias et al. (2017) do something similar for more disasters in Indonesia at the district level. They both suggest that satellite night-time imagery is a useful tool for assessing the post disaster impacts.[82]

[81] Several research papers have used night-time light to capture the immediate economic impact of floods, typhoon and other climate disasters (Tanaka et al., 2000; Bertinelli & Strobl, 2013; Mohan & Strobl, 2017; Del Valle et al., 2018).

[82] Hashetera et al. (1999) use the illumination intensity before and after the 1999 Marmara earthquake in Turkey to identify the impacted areas and provide information for the initial emergency response. Kohiyama et al. (2004) assess the immediate impact of the 2001

4.5 Data

Greater Christchurch includes Christchurch city and its satellite towns. According to the 2006 Census, the region's resident population count was nearly 425,000 with 82% living in Christchurch City. We aggregate and analyze all the data at the Area Unit level.[83] Based on the 2016 Geographic Boundary of Statistics New Zealand, there are 183 Area Units (AU) in Greater Christchurch, containing 158 AUs defined as residential areas.

4.5.1 Night-time Light Data

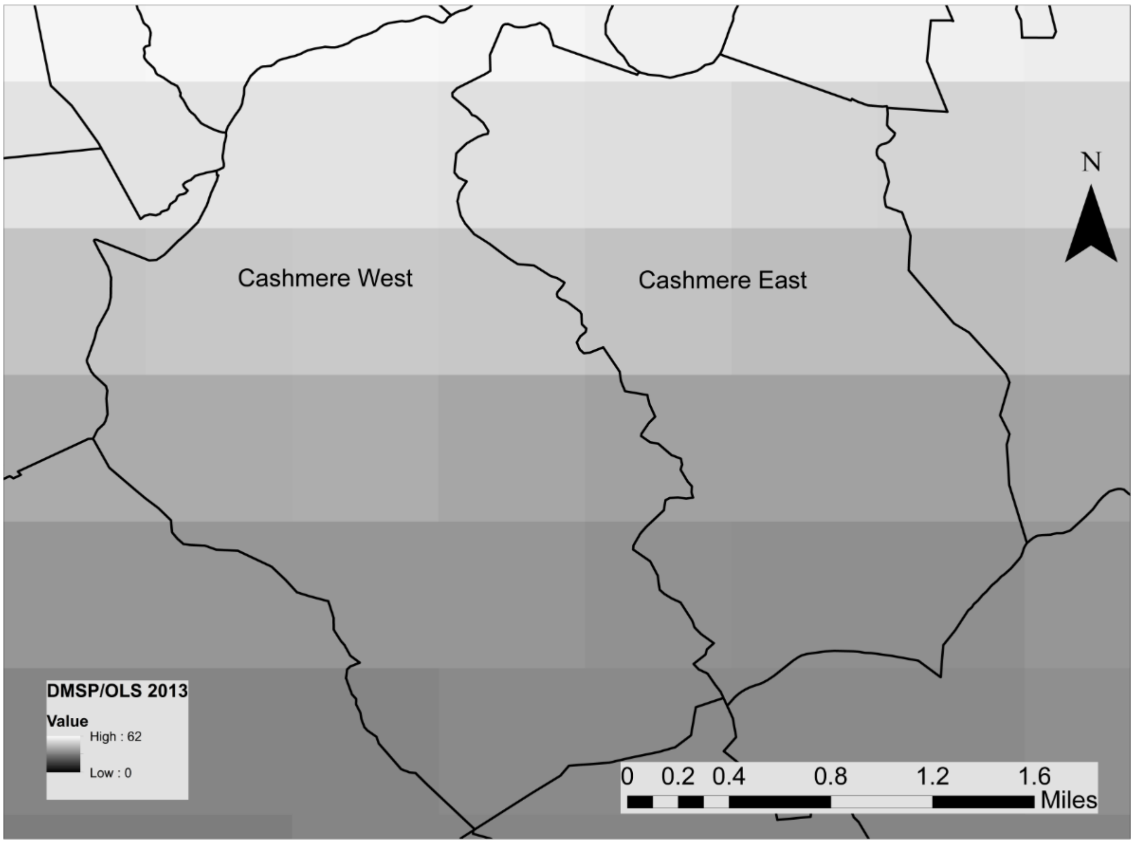
We use night-time light data derived from images taken by DMSP/OLS and VIIRS DNB.[84] We convert the images to integer format to obtain nightlight brightness at the pixel level. Because each AU has different size and can cover several pixels, we calculate the nightlight intensity weighted mean within each AU polygon. The scales of nightlight pixel and area unit are illustrated in figure 4-1. The figure shows the geographic boundaries of two Area Units, Cashmere West and Cashmere East, which are located in the south of the city. It is easy to observe from this figure that even within the city each AU may contain more than 10 pixels; less densely populated AUs may contain even more pixels. The average spatial area for an AU in Greater Christchurch is approximately 55 km^2.

Gujarat earthquake using night-time light intensity, and claim that the estimated loss from the night-time illumination intensity is consistent with their fieldwork information. Escudero et al. (2017) estimate the post-disaster recovery speed using nightlights for hurricanes in the Dominican Republic and Elliott et al. (2015) investigate typhoon damage in China.

[83] Area Units (AU) are aggregation of mesh-blocks (the smallest geographical unit used by Statistics New Zealand). AUs are non-administrative areas intermediate in size between mesh-blocks and territorial authorities. In urban areas, AUs are often a collection of several city blocks while in rural areas, AUs may be similar to localities or communities according to Statistics NZ.

[84] More explanations about the data sources and extraction procedures are available in the appendix. We used ArcGIS software to extract the light data from the TIFF night-time light raster images; which are available to download on the NOAA website.

Figure 4-1 Example of area unit polygons in south Christchurch and the DMSP/OLS light intensity pixels



Figures 4-2 and 4-3 present the night-time light images of Greater Christchurch from the 2013 cloud-free composite DMSP/OLS and VIIRS DNB satellites, respectively. The brightly lit area in the figures corresponds to Christchurch City. It is noticeable that the DMSP data have saturation centered on the city area while the VIIRS shows much more spatial detail. The latter has a better spatial resolution (about 750m) than the 2.7km resolution of the former (NOAA, 2013). Due to the difference in time coverage of the two datasets, both are used in this paper, but for the main results on insurance and recovery, we use the better VIIRS data.

Specifically, the DMSP data of satellite F16 and F18, from 2009 to 2012, are used to capture the reduction in nightlights as the indicator of short-run disaster impact.[85] For each AU, the average annual light intensity is available with higher values representing higher brightness. We then use the VIIRS data for the period from 2012 to 2016 for each AU. This data is available in monthly frequency, and we aggregate it to quarterly data.[86]

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[85] Due to the lack of on-board calibration, satellite shift and sensor degradation across different DMSP satellites (F10- 1992/94, F12- 1994/99, F14- 1997/03, F15- 2000/07, F16- 2004/09 and F18- 2010/13), the obtained digital number of night-time light series cannot be directly used to detect the temporal dynamics over a long period of time (Elvidge et al., 2009b; Zhang et al., 2016; Li & Zhou, 2017). In order to obtain comparable nightlight time series data for 2009-2012, we apply the inter-calibration procedure, suggested by Elvidge et al. (2014). This data is only available in annual frequency.

[86] We chose to aggregate the data to a quarterly area unit panel in order to smooth out some of the spatial and temporal volatility and noise present in the data. In principle, we could have conducted the analysis per pixel or per mesh-block (the smallest spatial unit Statistics NZ collects data in), but the existing evidence seems to suggest that nightlight will not be a good proxy for economic activity at such a high resolution. Furthermore, there are some doubts whether the impact of insurance payments is accurately measured enough so that it would be observable in the monthly data. Indeed, for robustness we also estimated the model using monthly data. However, none of the variables of interest seems to be statistically significant at that high frequency (these results are available in the online Appendix Table 7).

Figure 4-2 Raw image of night-time light in 2013, produced by DMSP/OLS

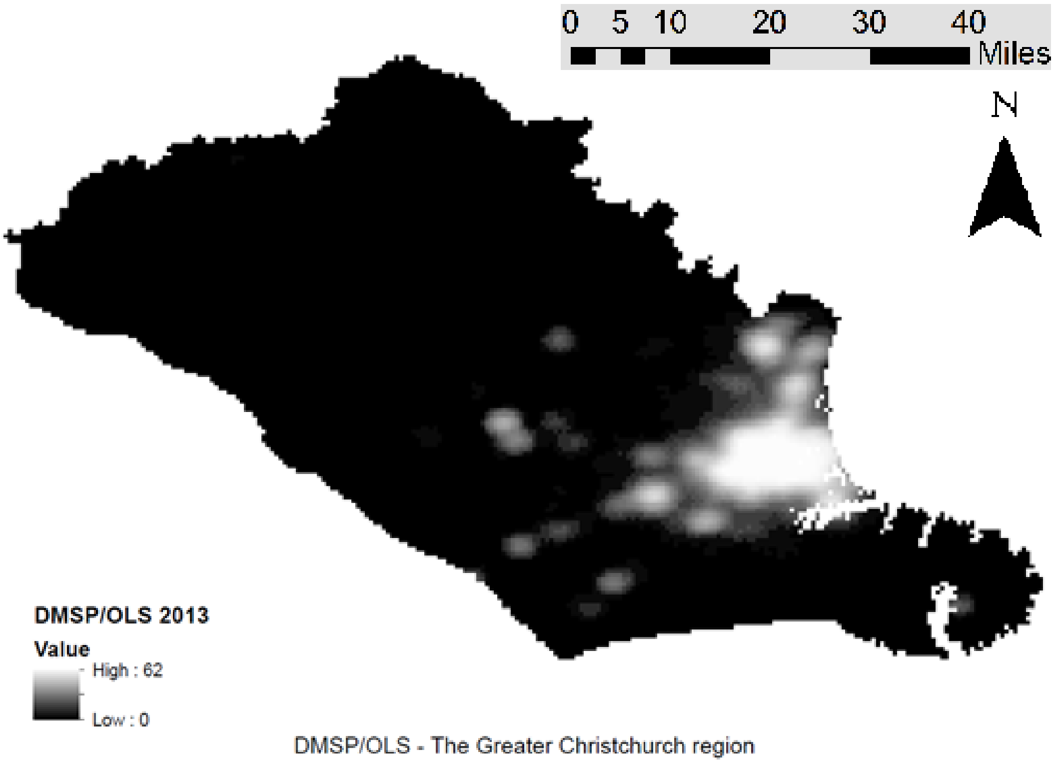


Figure 4-3 Raw image of night-time light in 2013, produced by VIIRS DNB

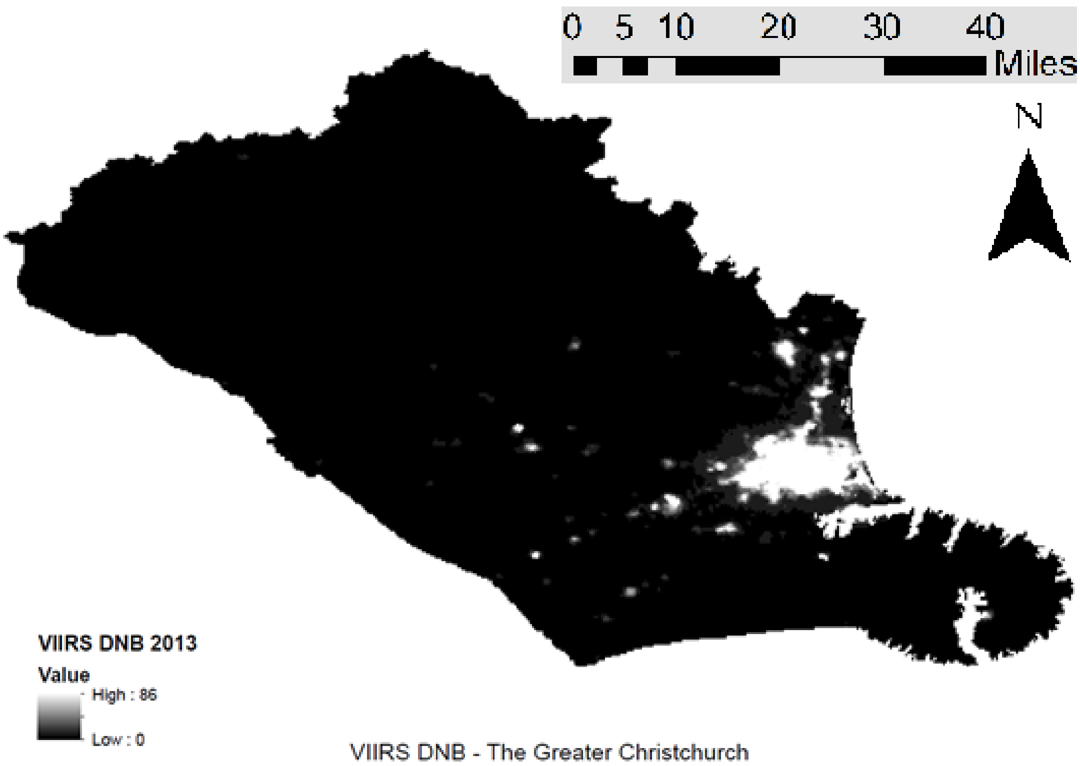


Figure 4-4 shows this AU-level aggregated data for 2013. This figure is directly comparable to Figure 4-3 that shows the same data still at the pixel level, before aggregation to AU. As elsewhere, night-time lights are much brighter in urban city centers. The Christchurch CBD (Central Business District), where most office buildings are located has measured light intensity constantly saturated at the highest level, compared to other areas in Greater Christchurch. AUs that are closer to the CBD have higher light brightness, though in the VIIRS data the AUs are not fully saturated (i.e. censored at the highest luminosity measure).[87,88]

Figure 4-5 shows the average annual night-time light, extracted from the monthly VIIRS imagery. The average annual light intensity increased steadily in the aftermath of the earthquakes, from 2012 to 2015, before declining and then rebounding slightly thereafter. The DMSP and VIIRS data are not comparable; even after radiometric inter-calibration undertaken by NOAA, comparison is impossible as the imageries were acquired at different times at night. We consequently do not link the two nightlight datasets.

[87] Henderson et al. (2012) express a concern that light emission is filtered away in low light intensity pixels in the older satellites, so that these might be inappropriately set to zero by the process of screening and filtering. In our region of interest, all the AUs have the average nightlight intensity higher than zero in both datasets. The AUs that have low nocturnal light emission are accurately measured in the VIIRS data, as the new satellite is able to detect dimmer lighting (Miller et al., 2012).

[88] For four summer months, the VIIRS data are unavailable for the whole region: Nov.-Dec. 2012, and Jan. and Dec.2013.

Figure 4-4 Average annual night-time light in 2013 at the area unit level

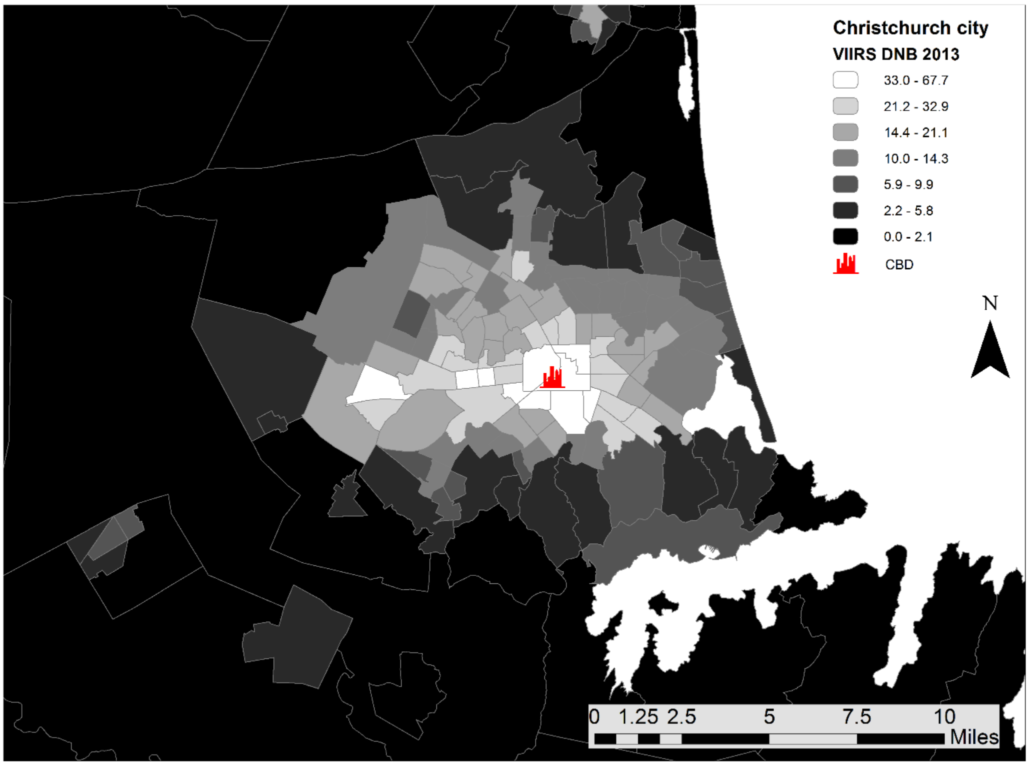
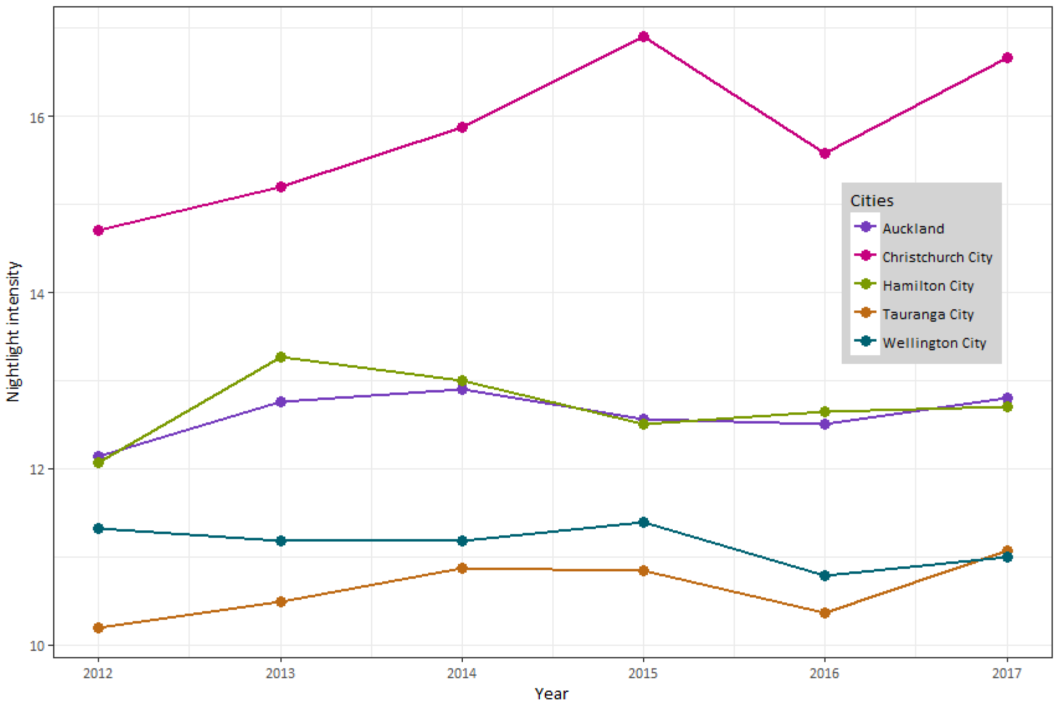


Figure 4-5 Average annual nightlight VIIRS –DNB for area units in Christchurch 2012 - 2017



4.5.2 *Insurance Claim Data*

To measure the payments provided by the insurance sector during the recovery, we use the geo-coded payment data from the EQC. The dataset includes individual claims for earthquake events during the 2010-2011 CES. For each insured event, the data provides the actual amount that EQC has spent on each property and the estimated total damage cost as it was apportioned for each earthquake event.[89] In this study, we use records of approximately 220,000 claims for nearly 100,000 properties in Greater Christchurch. More than 85 per cent of these claims came from Christchurch city. Three fourths of the claims are for building structure and the rest are for land and content exposure.[90]

Table 4-1 provides summary statistics of quarterly claim payment data at the AU level. In Greater Christchurch, the average total of quarterly claim payments for each exposure per AU are USD 462,696, USD 17,347, and USD 60,240 for structure, content and land, respectively.[91] The standard deviation of total land claim payment is high relative to its mean, as there are claims with very high land remediation cost due to land movement, rock fall and cliff collapse.[92]

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89 This estimated damage cost is the total insurance payment that EQC and private insurers would have transferred to the claimants (as insurance liability was based on replacement costs rather than the value of incurred damage). Nguyen and Noy (2019) provide further details about the earthquake residential insurance scheme in New Zealand and more detail about the EQC claim data.

90 The insurance claim payments across asset exposures (building structure, land and content) are highly correlated (see Table 4-7). Figure 4-10 provides the breakdown of EQC claims across districts and the separate earthquakes in 2010–2011. Even though the epicenter of the first event was located further away from Christchurch City, the number of valid claims for the first large earthquake is nearly as high as the latter's figure. However, in Christchurch city, there are fewer claims for the Darfield earthquake relative to the Lyttleton aftershock.

91 In Christchurch, the value of exposed assets for building structures is much higher than for contents and land values.

92 EQC does not only covered for the visible land damage, but the scheme has also been found liable for ground improvement works or long-term reduction of property values due to increased flood and liquefaction vulnerabilities generated by the earthquakes. As far as

we know, EQC is the only insurance scheme globally that offers compensation for such risks.

Table 4-1 Summary statistics of claim payment data

VARIABLES	Building (N = 143,545)		Content (N = 68,324)		Land (N = 73,123)		Total (N = 220,898)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total claim payment (USD)	462,695	696,423	17,347	43,840	60,240	1,424,564	540,284	1,642,358
Total exposed value of the assets (USD)	6,680,840	7,645,051	274,319	520,982	694,532	2,844,193	7,651,877	9,406,143
Proportion of cash paid/total settlement	0.73	0.26	1	0	0.55	0.41	0.71	0.35
Time to settlement (days)	845	538	489	439	688	514	984	542

Note: Claim payments are aggregated at AU level and quarterly frequency. Summary statistics of variable "Time to settlement" are calculated at the individual claim level.

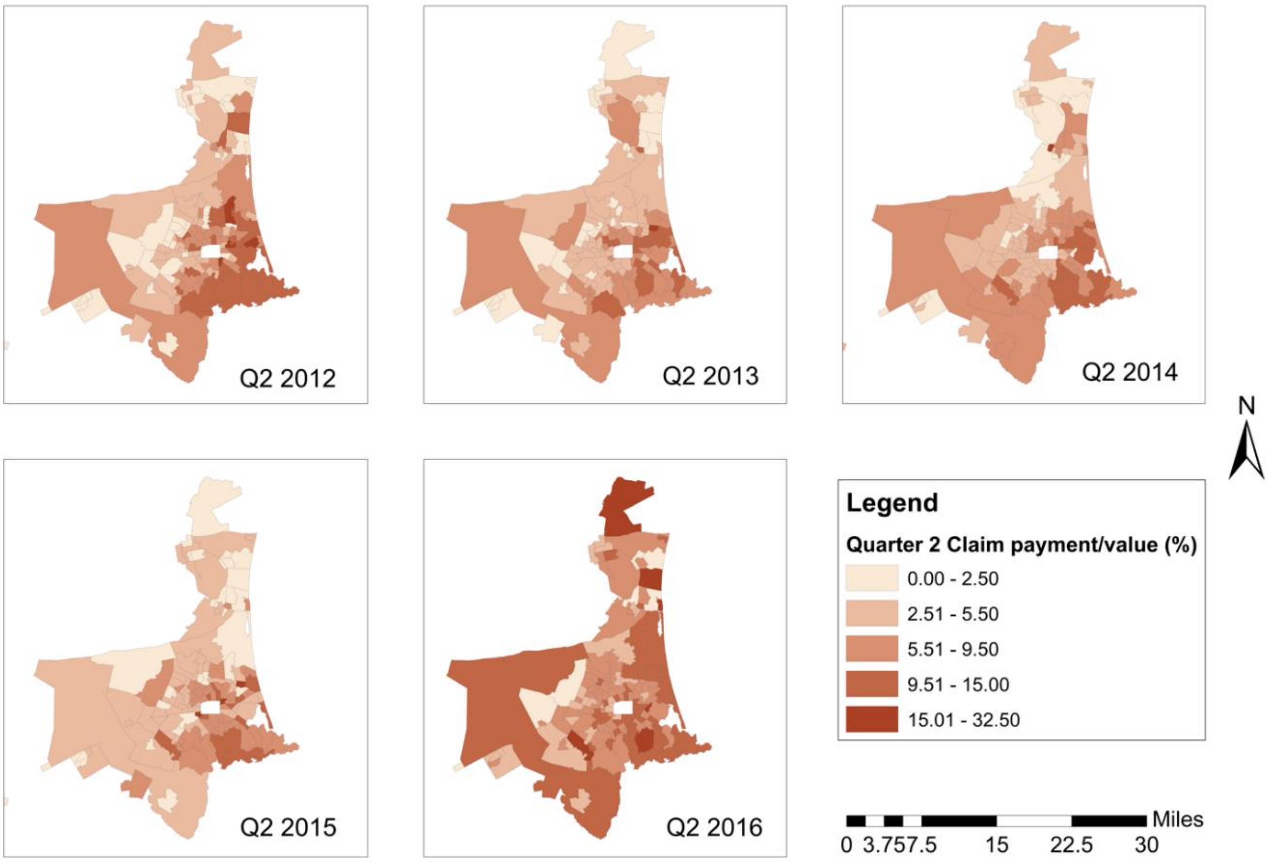
Table 4-2 Summary statistics of Area Units (AU) in Greater Christchurch

VARIABLES	Christchurch city		Waimakariri and Selwyn	
	Mean	**St. Dev.**	**Mean**	**St. Dev.**
Area in squared km	11.3	44	148.2	612.4
Night-time population	1,755	1,183	1,643	1,255
Night-time population density	2,802	1,296	514	698
Household income	68,420	18,220	74,171	18,345
Household income density	40,893	28,853	25,097	29,778

Note: Household income and night-time population are measured using 2006 Censuses. The density variables are per km^2.

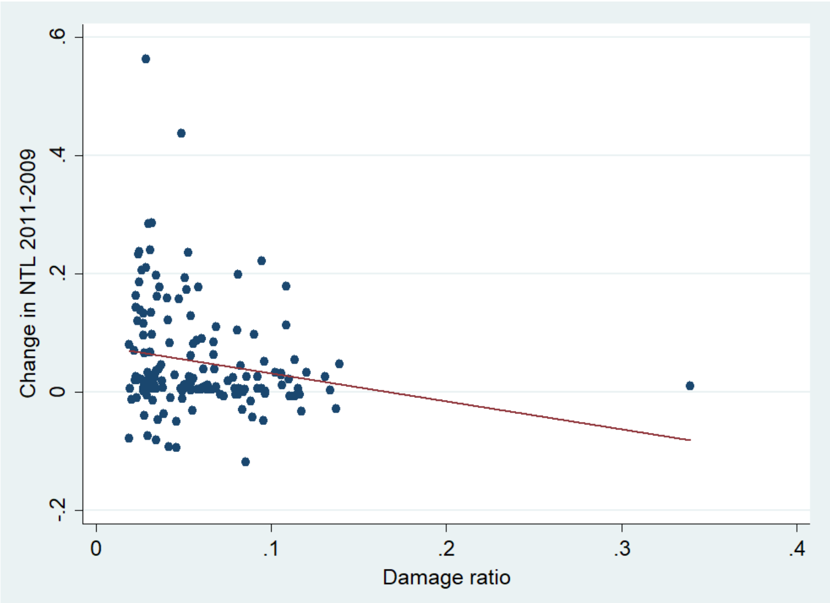
We also exploit other information in the EQC data; in particular we focus on two variables: time it took to settle the claim, and proportion of cash in settlement. The first is the average number of days to claim settlement, since the day the claim was launched, for each quarter in each AU. Figure 4-6 presents the temporal distribution of payments (per AU) for Q2 of each of the years following the earthquakes (a fuller representation of all quarters is available in the online appendix as a short stop-motion clip). There is no apparent spatial pattern in these claim payments, suggesting there is most likely no selection problem in the time-to-payment variable.

Figure 4-6 Quarter 2 (2012-2016) claim payment intensity, per area unit



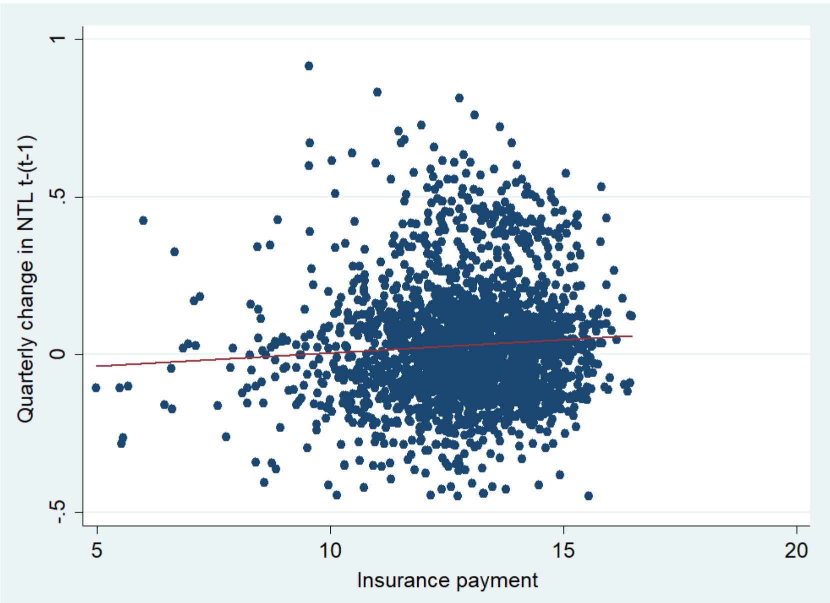
The second variable is the proportion of cash payment amount relative to the total claim settlement in each AU. Table 4-1 illustrates that 71 percent of the amount the insurer paid to claimants was in cash, while the number of cash-paid claims was 60 per cent (EQC, 2017). As discussed above, it took between 1 to 4 years for most claims to be resolved (average is nearly 3 years). Figures 4-7 and 4-8 describe the association between the insurance claim data and the measured nightlights, both for the immediate impact phase in Figure 4-7, and for the longer-term recovery period (in Figure 4-8).

Figure 4-7 Change in Nightlight from 2009 to 2011 and Damage ratio



Note: The y-axis variable is described in equation (1), the x-axis variable is defined in equation (2).

Figure 4-8 Quarterly change in NTL and same quarter insurance payments



Note: The y-axis variable is described in equation (4), the x-axis variable is defined in equation (5).

4.5.3 *Other Variables*

We also use data from Statistics New Zealand, which provides information regarding households at the AU level from the most recent census conducted before the earthquakes (in 2006) - this data is summarized in table 4-2. The EQC claim data and census data were both matched with the night-time light data at the AU level. Table 4-8 illustrates the correlation between the 2006 nightlight and control variables from the 2006 Census. There are positive correlations between light luminosity as a measure of economic activity and most explanatory variables.[93] Table 4-8 also shows that light intensity captures the density variables better. For instance, the correlation between nightlight and population is 0.587, which could be compared with the correlation between nightlight and population density (0.709). There is also positive relationship between light brightness and income density; and nocturnal light is negatively correlated with the distance between the AUs and the city center.

The last data we use here are Shake-maps for the September 2010 and February 2011 earthquakes, provided by the USGS Earthquake Hazard Program.[94] These maps provide the spatial distribution of the physical intensity for major earthquakes. We aggregate these macro-seismic intensities to AU level and use them in our empirical models. In all of our empirical estimations, we exclude the CBD area because the area was cordoned off for two years, and its redevelopment was subject to a very different, complex, and contentious regulatory regime.[95]

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[93] However, the correlation in levels is not as high as the estimates from other previous nightlight research at more aggregate regional or country level.

[94] Seismologists have started to produce detailed shake maps for major earthquakes. The maps capture the exact spatial extend of earth surface movements and their decay in magnitude across space (that decay is not linear in distance and depends on surface conditions).

[95] The CBD area is mainly commercial buildings, which therefore captures a different facet of the recovery. The residential claim payment variable we use is likely to mis-measure

4.6 Methodology

We now turn to the regression analysis where we explore the change in night-time light in the Greater Christchurch region, during and after the CES. We present two set of results. The preliminary set of estimations, described in section 6.1, is intended to establish the short-term impact of earthquake damage on local economic activity in Great Christchurch. The second, the focus of this work, aims to estimate the effect of insurance payments on the recovery of local residential areas in the region (section 6.2).

4.6.1 Earthquake Damage and the Loss in Night-time Light

As already shown in figure 4-5, the nightlights had declined between 2010 and 2011 and have been recovering since 2012. We begin by using the immediate reduction in luminosity post- earthquakes as an indicator of the loss in economic activity in Greater Christchurch. The variable is calculated as follows

$$Economic\_Loss_i^{eq} = \Delta NTL_i^{2009-2011} = \ln(NTL_{i,2009}) - \ln(NTL_{i,2011}) \quad (1)$$

where NTL_i is our economic development indicator based on the DMSP nightlight value (taken in logarithms) in each AU (denoted by i). We next aggregate the insurance claim payments over the whole period, to the AU level, to indicate the financial loss experienced by each AU due to earthquake damage. A number of papers in the literature have stressed that earthquake damage is correlated with income per capita (Kahn, 2005; Toya & Skidmore, 2007; Felbermayr & Gröschl, 2014). Hence, even in the spatially confined study at hand, cross-AU heterogeneity in damage may be driven by cross-AU differences in income per capita. To reduce the endogeneity of the financial loss indicator, we create a damage ratio variable from these aggregate figures (in equation 2).

the actual impact of the earthquakes in the CBD. In any case, including the few residential CBD observations in the estimated sample does not change any of the results reported below.

$$Damage_{i,k} = \frac{Claim\_payment_{i,k}}{\sum_k Asset\_value_{i,k}} \quad (2)$$

$Damage_i$ represents the total earthquake financial loss on all exposures (k = building, content, land, or total exposure) as a ratio of the total exposure value for all dwellings for which there were claims in area unit i.[96] The property value data is obtained from the New Zealand quotable value (QV) data.[97]

In the first set of results, we use $Economic\_Loss_i^{eq}$ as a dependent variable indicating the change in economic activity due to the earthquakes. We hypothesize that AUs that have high ΔNTL experienced large economic losses because of the large amount of damage to property (assets), as follows:

$$Economic\_Loss_i^{eq} = \alpha + \beta_k Damage_{i,k} + \gamma X_i + \varepsilon_i \quad (3)$$

Where $Damage_{i,k}$ is earthquake damage (building, content, land, or total) as a ratio of exposed value for each AU as specified in equations (2). We use robust standard errors in order to control for the heteroscedasticity in the error terms. In addition, for robustness we include several control variables[98] (X_i) that might also affect the measured economic loss in our regressions such as average household income, night-time population, average number of bedrooms in each household and surface area (taken in logarithms).

The next robustness check for endogeneity leads us to implement a two-stage least squares (2SLS) method in the specifications. We use the earthquakes' physical intensity measure (Z_i) as an instrumental variable for $Damage_{i,k}$. We expect that the 2SLS method will give us a similar finding as the main regression. The correlations between damage ratio measured by property

[96] As almost all houses were insured, the deductible was very low, and almost all houses incurred some damage (even if minor), this sum approximates quite closely the total value of all residential assets in each AU.

[97] QV data is used by local authorities in their assessments of property tax liabilities.

[98] The correlations between damage ratio and other variables are shown in the online appendix.

damage and the macro-seismic intensity of February 2011 earthquake are over 50%, except for land damage.[99] Thus, we expect to have strong first stage where the instrument is highly correlated with the endogenous variable.[100]

4.6.2 *Insurance settlement and Christchurch recovery*

In the second set of regressions, we estimate the effect of insurance payments on local recovery in the Greater Christchurch region, following the earthquakes. In this regression, due to the limited availability of the data, we use the night-time VIIRS light dataset from April 2012 to August 2016 (VIIRS data is not available before that). We convert the nightlight data from monthly to quarter frequency t for AU i. In order to identify the economic recovery in Greater Christchurch, we take the proportional change in the night-time radiance value for each quarter. In the specification, the variable is used as dependent variable.

$$Economic\_Recovery_{i,t}^{Post} = \Delta NTL_{i,t}^{Q2.2012-Q3.2016} = \ln(NTL_{i,t}) - \ln(NTL_{i,t-1}) \quad (4)$$

The main explanatory variable is the insurance payment. It is the total insurance claim pay-out which an AU received at quarter t, as described in equation (5).

$$Ins_{i,t,k} = \ln(Claim\_payment_{i,t,k}) \quad (5)$$

The regression model is written as follow:

$$Economic\_Recovery_{i,t}^{Post} = \alpha_i + \tau_t + \beta_k Ins_{i,t,k} + \gamma X_{i,t} + \varepsilon_{i,t} \quad (6)$$

Whereby $Ins_{i,t,k}$ is our measure of insurance payments described in equation (5). Here, we hypothesize that the insurance payments are associated with the

[99] See the online Appendix.

[100] We assume that the effect of earthquakes' physical intensity (Z_i) on $Economic\_Loss_i^{eq}$ only come from our endogenous explanatory variables - $Damage_{i,k}$. When we run the tests of endogeneity, the null hypothesis (H_0: damage ratio variable is exogenous) get rejected at 5% and 1% significance level.

quarterly change in nightlight in the years following the earthquakes (Q2 2012 to Q3 2016). We included AU and quarter fixed-effects to control for unobserved variations across individual AUs and over time. We also include AU cluster-robust standard errors to control for heteroscedasticity. Other insurance-related variables such as 'settlement time', and 'proportion cash settlement amount' are also included, as discussed in the previous section.

In some AUs, there are quarters without claim payments. The value of the insurance related variables in this case is set as one.[101] We also investigate the interaction term between insurance payment and settlement time (assuming that delayed payments may have a different impact than the prompt ones). EQC and private insurers resolved insurance claim as a first come, first serve basis without prioritizing any certain demographic groups or geographic location. Hence, we assume that the claim settlements were processed randomly across locations. This may help to identify areas of variation explaining the recovery process requiring further analysis.

In addition, we carry out spatial panel data analysis. Spatial econometric modeling helps us control for spatial effects. Spatial panel models may reduce the unobserved estimation bias which arises from both spatial and time dependence. More importantly, spatial regression methods permit us to identify spillover effects coming from neighboring AUs over time (Anselin et al., 2008; Lee & Yu, 2010; Elhorst, 2014).[102]

Following this literature, we implement four different spatial specifications including Spatial Autoregressive Model (SAR), Spatial Error Model (SEM),

[101] So that their log value will be equal to zero.

[102] Spatial models have been used in economic geography, urban and regional science (Baltagi & Li, 2004; Kelejian & Piras, 2014; Firmino et al., 2016; Taupo et al., 2018).

Spatial Durbin Model (SDM) and Spatial Autocorrelation Model (SAC).[103] We employ spatial panel Maximum Likelihood estimation for the set of regression models with AU and quarter fixed effects as described below.

SAR) $$Y_{i,t} = \alpha_i + \tau_t + \rho W Y_{i,t} + \beta X_{i,t} + \varepsilon_{i,t} \quad (7)$$

SEM) $$Y_{i,t} = \alpha_i + \tau_t + \beta X_{i,t} + \vartheta_{i,t} \quad \text{where } \vartheta_{i,t} = \lambda W \vartheta_{i,t} + \varepsilon_{i,t} \quad (8)$$

SDM) $$Y_{i,t} = \alpha_i + \tau_t + \rho W Y_{i,t} + \beta X_{i,t} + W X_{i,t}\theta + \varepsilon_{i,t} \quad (9)$$

SAC) $$Y_{i,t} = \alpha_i + \tau_t + \rho W Y_{i,t} + \beta X_{i,t} + \vartheta_{i,t} \quad \text{where } \vartheta_{i,t} = \lambda W \vartheta_{i,t} + \varepsilon_{i,t} \quad (10)$$

These models include three different types of interaction effects among units: (i) endogenous spatial interaction effects among the dependent variable ($WY_{i,t}$); (ii) exogenous spatial interaction effects among the explanatory variables ($WX_{i,t}$); and (iii) spatial interaction effects among the error terms ($W\vartheta_{i,t}$). The parameter ρ is the spatial autoregressive coefficient, while θ and λ are the spatial-response and spatial-autocorrelation coefficients, respectively.

W is referred to the non-negative spatial weighted matrix ($N \times N$) that describes the spatial structure of dependence between AUs in the sample. In this study, we employ the row-standardized contiguity weighted matrix. The elements ω_{ij} of matrix W equals to $1/$ the number of neighbors of AU i if AU i and j share the border, otherwise $\omega_{ij} = 0$. Our spatial models, therefore, emphasize the geographical contiguity between AUs, rather than the physical distance. The next section describes the results of these estimations.

4.7 Results

The first set of regressions results, examining whether earthquake damages explain the reduction in economic activity in Greater Christchurch, are shown

[103] We exclude the general nesting spatial (GNS) model, which include all the interaction effects' types, due to concerns of overfitting and over-identification (Manski 1993; Elhorst, 2014).The GNS model is seldom used in applied spatial research (LeSage & Pace, 2009).

in table 4-3. The damage ratio variable is the main explanatory variable in the regressions. In columns 1-3 of the table, we estimate the effect of residential building damage on the economic activity in the immediate aftermath of the earthquake events. Other columns focus on the damage for content, land and total damage (sum of the three asset classes). In these specifications, the coefficients of damage variables for buildings (and totals) are always positive and significant (they are mostly positive but insignificant for the content and land damage variables – see columns 4-9). For instance, in column 1 of table 4-3, the economic loss will be 0.56 percent higher, when the residential buildings damage over property value increases by 1 percent. When controlling for other variables (taken in logarithms), the building damage indicators are still statistically significant and of the same order of magnitude. Maybe not surprisingly, overall, the earthquakes' residential building damage appears to explain some of the economic loss immediately after the disaster; and it is the only variable that consistently has explanatory power.

The control variables 'household income' and 'number of bedrooms', which indicate the size of a dwelling, have small and insignificant coefficients across regressions of all asset classes; these results contrast with cross-country work that does identify correlation between per capita wealth and income and disaster damage (e.g., Kahn, 2005). Moreover, when using the earthquakes' physical intensities as instrumental variables[104] (column 3, 6, 9 and 12) provide us with similar results to the OLS regressions (with higher magnitudes for the coefficient estimates). The magnitude of the damage ratio coefficient is stronger for building and total assets regressions. For instance, a 1 percent increase in the total asset damage over its value is associated with 0.91 percent reduction in residential economic activity on average.

[104] The 1st stage R-squared of the regressions are between 0.4 – 0.5 for different asset classes.

Table 4-3 Short run economic impact of the earthquakes using the damage ratio variable

VARIABLES	Dependent variable: Change in night-time light between 2010 and 2011											
		Building			**Content**			**Land**			**Total**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Damage ratio	0.559***	0.416**	0.957**	0.757**	0.379	0.379	0.016	-0.006	0.747	0.474***	0.343**	0.912**
	(0.186)	(0.171)	(0.401)	(0.367)	(0.389)	(0.389)	(0.051)	(0.068)	(0.493)	(0.181)	(0.162)	(0.415)
Household Income		0.008	0.003		0.007	0.007		0.012	-0.025		0.007	0
		(0.037)	(0.045)		(0.036)	(0.036)		(0.038)	(0.049)		(0.037)	(0.041)
Night-time Population		0.018	0.017		0.019	0.019		0.019	0.021*		0.019	0.017
		(0.012)	(0.012)		(0.012)	(0.012)		(0.012)	(0.012)		(0.012)	(0.012)
Number of Bedrooms		-0.06	-0.019		-0.071	-0.071		-0.093	0.023		-0.061	-0.011
		(0.094)	(0.119)		(0.092)	(0.092)		(0.092)	(0.144)		(0.092)	(0.114)
Area square Km		0.006	0.005		0.006	0.006		0.006	-0.012		0.005	0.003
		(0.008)	(0.008)		(0.008)	(0.008)		(0.009)	(0.018)		(0.008)	(0.009)
Constant	-0.086***	-0.237	-0.251	-0.076***	-0.21	-0.21	-0.052***	-0.228	0.011	-0.079***	-0.224	-0.221
	(0.016)	(0.312)	(0.367)	(0.016)	(0.301)	(0.301)	(0.008)	(0.309)	(0.362)	(0.0151)	(0.305)	(0.335)
Observation	158	158	158	158	158	158	158	158	158	158	158	158
R-squared	0.045	0.097	0.058	0.022	0.079	0.079	0	0.074	0.031	0.037	0.093	0.043
IV			40.349			35.301			3.171			22.328

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. All regressions are estimated with OLS. IV is the robust Kleinbergen-Paap rk Wald F statistic for test of weak instruments. IV regressions have overidentification's p-value approximately equal to zero, except for land regression.

For the second set of regressions, our primary focus in this paper, we examine the effect of insurance payment on local economic recovery post-earthquakes. Table 4-4 provides the results for the estimations of equation (6) including AU and quarter fixed-effects. The insurance payment variables are estimated for each exposure separately (columns 1-6) and total exposure is provided in the last three columns.

The estimated coefficients for the main variable are small and insignificant when other insurance variables are not included (columns 1, 4, and 7), or when we also control for the time of claim settlements, and the proportion of claims paid in cash (columns 2, 5, and 8). Nevertheless, the insurance payment variables are positive and significant when we control for the interaction between the amount of insurance payment and the other variables characterizing those payments (time to settlement and proportion in cash) - see columns 3, 6, and 9). The estimated coefficients are positive and are statistically significant especially for the largest exposure (building damage). In column 3, the coefficient for insurance payment is 0.071 which captures the effect for a settlement time of zero. Not surprisingly, payments for damage to contents (not shown) and to land (columns 4-6), which are relatively small, are associated with very small coefficient estimates, and do not have any statistically discernible impact on recovery.

In the bottom row of each column (each regression) we aggregate the impact of insurance payments, by also accounting for the interaction effects with the time and cash variables.[105] The total effect is positive but is not statistically significant. In other word, insurance payment matters if and only if it is paid out immediately. When taking settlement time into account, the effect of insurance payment is insignificant. Time to claim settlement is important for the recovery process. This finding is important. It is the first time, as far as we know, that detailed post-catastrophe insurance payments are empirically linked with better local economic recovery outcomes.[106]

The effect of the settlement time variable on the outcome variable is negative, as we hypothesized. Both the variable in levels, and its interaction term with payment size are negative and significant (column 3 and 9) for claims for building damage. In other word, the positive impact of the claim amount is reduced when the settlement process is delayed – i.e., delayed payments are less helpful in generating increased economic activity. This might be because with delayed payments the owner of a 'delayed' property may have already moved elsewhere or had already fixed her house without insurance funding, but to a lower standard.

The coefficient of the proportion of cash settlement variable[107] is negative and statistically significant for building structure and total assets (column 2 and 8).

[105] The aggregated effect of insurance payment is the sum of the insurance payment coefficient and the product of its interaction terms' coefficients with the means of time settlement and cash variables.

[106] Von Peter et al. (2012), in a widely cited paper, found an association between overall insurance coverage and post disaster GDP growth at the national level.

[107] The variable is excluded in the content specification because all the content payments were settled in cash.

It was suggested, in New Zealand and elsewhere, that cash payments of insurance claims enable recipients to move away and not rebuild. While we find some supportive evidence of that in these results, once we include the interaction terms (between cash proportions and the aggregate amount of payments) we no longer find this negative effect. If anything, our regression results show evidence that payments in cash did not necessarily hinder (nor assist) in the process of recovery.

In the specifications in table 4, we also control for the variations across time using the quarter dummies. The coefficients of the quarter dummies are large and volatile for the first 2 years after the CES, their coefficient estimates become smaller in absolute term from 2014 onward. Economic recovery in residential areas occurred mainly in 2012 and 2013 and the recovery rate thus declines as time passes.

To further test the robustness of our results, we re-ran similar specifications using spatial panel models– this allows us to control for the spatial dependencies in the regression set. Appendix Tables 4-10, 4-11 and 4-12 report the estimation results examining the effect of insurance payment on local recovery for the different spatial econometric models described in the appendix. The finding using the spatial models are quite similar to the results of the non-spatial regressions presented in table 4-4. Building and land specifications have significant coefficients, while content regressions do not.

The payment*time interaction term is, as was the case in previous specifications, negative and statistically significant.

We carry out model selection tests (Anselin et al., 1996; Olivia et al., 2009; Belotti et al., 2016; Noy et al., 2016), these support the SDM model specification. In addition, we also implement the Hausman test for the spatial panel model to test whether random effect models are preferred. The estimated spatial autoregressive (ρ) and autocorrelation (λ) coefficients are significant. The economic recovery of an AU is positively influenced by the recovery of other surrounding AUs. Because the estimation coefficients of the specifications cannot be compared with each other, we derive the direct and spillover effects.[108] In general, a 1 percent increase in insurance payment directly leads to 0.4–0.5 percent increase in residential recovery. However, this direct positive effect would be reduced when the claim settlement was delayed.

If the spatial regression models include the endogenous interaction term $(WY_{i,t})$, the direct effects contain the feedback effects in their estimates. The feedback effects occur when the impact goes through neighboring AUs and back to the initial AU (LeSage & Pace, 2009). In our result, when taking the difference between direct effect and point estimate, the feedback effect only accounts for about 10 - 12 percent of the direct effect. Generally, higher

[108] To obtain the direct and spillover effects estimates, we use the variation of 500 simulated parameter combinations drawn from the multivariate normal distribution implied by the Maximum Likelihood estimation. This procedure is widely used in spatial statistic inferences (LeSage & Pace, 2009; Vega & Elhorst, 2015).

insurance payment received in an AU does not only lead to better economic recovery locally, but it also increases the economic growth in neighboring AUs. The spillover effect of the delay in claim payment is also observable in these spatial models.

Table 4-4 Economic recovery following the earthquakes (Claim payment) – AU and quarter fixed effect

	Dependent variable: Quarterly change in night-time light								
VARIABLES	Building			Land			Total		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Insurance payment	0.004 (0.004)	0.005 (0.004)	0.071* (0.038)	0.000 (0.001)	-0.000 (0.001)	0.009 (0.009)	0.004 (0.004)	0.004 (0.004)	0.094*** (0.031)
Settlement time		0.017 (0.033)	-0.112* (0.058)		0.011*** (0.004)	-0.001 (0.012)		0.031 (0.030)	-0.121** (0.054)
Prop. cash settlement		-0.060*** (0.022)	-0.018 (0.157)		0.011 (0.010)	-0.012 (0.028)		-0.056*** (0.021)	-0.110 (0.125)
Ins. payment* Settlement time			-0.011*** (0.005)			-0.012 (0.001)			-0.010*** (0.006)
Ins. payment* Prop. cash settlement			0.007 (0.014)			0.000 (0.003)			0.005 (0.010)
Constant	0.146*** (0.052)	0.203 (0.224)	0.664 (0.495)	0.101*** (0.013)	0.171*** (0.024)	-0.106 (0.072)	0.145*** (0.053)	0.283 (0.195)	0.857* (0.436)
Observation	2686	2686	2686	2686	2686	2686	2686	2686	2686
N.o Area Units	158	158	158	158	158	158	158	158	158
R-squared	0.704	0.705	0.706	0.703	0.704	0.704	0.704	0.705	0.706
Total effect of Ins. payment	0.004 (0.004)	0.005 (0.004)	0.009 (0.049)	0.000 (0.001)	-0.000 (0.001)	0.002 (0.011)	0.004 (0.004)	0.004 (0.004)	0.030 (0.049)

***/**/* Indicating the significance levels of 1%, 5% and 10%. AU cluster and robust standard errors are shown in parentheses. All regressions are estimated with AU and quarter fixed effect. Columns (1)-(3) measure the 'insurance payment' for building damages (per AU and quarter), columns (4)-(6) measure the payments for land damage, and columns (7)-(9) sum up the building, contents, and land payments together. In all columns, the dependent variable is the same.

4.8 Conclusion

Very few papers have examined economic recovery in the longer-term (beyond the first two years), and none have looked at the role of insurance in facilitating recovery at the local level. This lacuna is mainly due to the limited availability of the required data at the appropriate frequency and over the longer term. Our contribution to the empirical literature is twofold: First, we show one can measure the immediate economic impact and the economic recovery of local areas after a sequence of earthquakes using the change in night-time luminosity. Second, we used data on insurance claim payments to examine the effectiveness of these payments in facilitating recovery.

We found that the earthquake damage significantly reduced the nightlight radiance in the immediate aftermath of these events, and that the amount of lights bounced back and even increased in the years that followed. Using the insurance payment information, we found that building claim payments contributed significantly to local residential recovery if it is paid immediately. Prolonged settlement delays (in cases when these delayed occurred) reduced the benefits of these insurance payments. Time to claim settlement is an important factor for recovery. We also found that settling claims in cash (versus doing the required reconstruction) did not change the dynamics of recovery in any material way. We also quantify the positive spillover effects of insurance payments to the recovery of other neighboring area units.

As far as we are aware, the average time it took to settle claims was remarkably longer in Christchurch as almost every residential property that was damaged (and almost all were) was also insured. Yet, delays are by no means unique. Complaints about the time it takes to settle claims appear after almost every large insured event. As other countries increase the penetration rates for insurance for natural hazards, this problem may further exacerbate in other jurisdictions as well.

It is also important to note that while public earthquake insurance is less prevalent, and less often used, there are many publicly funded programs for flood insurance in many different countries (and not only in high-income countries). Flood insurance programs may suffer from the same weaknesses as the risk is correlated across larger spatial areas than earthquake risk is. The recent events associated with the 2017 Atlantic Hurricane season (especially Hurricane Harvey, which was the most heavily insured) have amply demonstrated that. The role of insurance in the recovery of Houston should clearly be of concern to policymakers and the residents there, and unfortunately, in future events that are bound to occur in many places around the world.

Appendix - Night-time Light Data

Satellites from the U.S Air Force Defense Meteorological Satellite Program (DMSP) have been recording anthropogenic light present at the earth's surface with their Operational Linescan System (OLS) sensors by NOAA since the 1970s. The DMSP satellites observed the lights of all surfaces on the planet between 8:30pm to 9:30pm every night (Elvidge et al., 2001). However, the DMSP cloud-free composited stable light data that NOAA makes available appear to have several weaknesses: only annual frequency, limited spatial resolution, saturation in bright metropolitan areas, no on-board calibration, and absence of low-light spectral bands for discriminating different types of lighting (Elvidge et al., 2007; Elvidge et al., 2010).[109]

In contrast, the day-night band (DNB) of the Visible Infrared Imaging Radiometer Suite (VIIRS) offered many improvements. This new generation night-time light data was released in 2012 and surpass its predecessor in term of radiometric accuracy, radiance range, on board calibration system, and spatial resolution (Baugh et al., 2013; Jing et al., 2016).[110] The overpass time of Suomi-NPP is midnight to 1:30am. Although there is a decline in outdoor lighting for urban areas after 10:00pm, the VIIRS DNB still detects plenty of lighting indicated by human development (Elvidge et al., 2013). The monthly DNB composite data is increasingly used in social science research. Li et al. (2013) suggest that VIIRS DNB nightlight data has a stronger capacity to proxy for gross regional product than the DMSP-OLS data, using a case study of counties and provinces in China (see also: (Ma et al., 2014; Shi et al., 2014).

[109] The DMSP cloud-free composited stable light product capture the lights from urban areas, towns and places with persistent bright lighting. The noises of the background are detected and replaced with zero value. DMSP digital values range from 0-63. The lighting value for areas with no cloud-free observations within a year are set as 255.

[110] DNB can be considered as a radiometer. It has an onboard calibration system to generate the radiances for Earth observations. In contrast, DMSP/OLS only has an image sensor and does not equip the onboard calibration.

Appendix Table

Table 4-5 Correlation table between Damage ratio and other variables

VARIABLES	Damage ratio			
	Building	**Content**	**Land**	**Total**
Household income	-0.117***	-0.086***	0.098***	-0.086***
Night-time Population	0.195***	0.246**	-0.016***	0.171***
Number of bedrooms	-0.243***	-0.278***	0.003**	-0.220***
Area square Km	-0.031***	-0.011***	0.283**	0.029***
Sep 2010 eq. intensity	-0.012***	-0.044***	-0.139***	-0.055***
Feb 2011 eq. intensity	0.587***	0.514***	0.088***	0.511***

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%.

Table 4-6 Correlation between different insured exposures

	Building	**Content**	**Land**
Building	1		
Content	.845**	1	
Land	.645**	.639**	1

Table 4-7 Correlations between nightlight and control variables

VARIABLES	Night-time light intensity	
	Correlation	% of the variation explained
Night-time population	.587**	34.47
Night-time population density	.709**	50.29
Household income	-.299**	8.94
Household income density	.479**	23.01
No. occupied dwellings	.585**	34.23
No. occupied dwellings density	.727**	52.86
Distance from CBD	-.831**	69.05

Table 4-8 Correlations between nightlight and control variables in FE regressions

VARIABLES	Night-time light intensity		
	Correlation	% of the variation explained (overall R^2)	Beta Coefficient
Night-time population	0.356**	12.39	0.248***
Night-time population density	0.852**	68.84	0.248***
Household income	-0.217**	4.18	-0.242*
Household income density	0.889**	58.32	-0.242*
No. occupied dwellings	0.380**	13.99	0.251***
No. occupied dwellings density	0.854**	70.31	0.251***

These are based on univariate panel regressions with AUs and time fixed effect and using DMSP nightlights from 2006 and 2013, and the corresponding Censuses.

Table 4-9 Economic recovery following the earthquakes (Claim payment) – Direct and Indirect effects (Nearest-neighbor matrix)

	Dependent variable: Quarterly change in night-time light											
VARIABLES	**SAR**			**SAC**			**SEM**			**SDM**		
	Building	**Land**	**Total**	**Building**	**Land**	**Total**	**Building**	**Land**	**Total**	**Building**	**Land**	**Total**
Direct effect												
Insurance payment	0.050	0.008	0.068**	0.048	0.008	0.063**	0.050	0.004	0.065**	0.034	0.005	0.056
	(0.033)	(0.009)	(0.027)	(0.031)	(0.009)	(0.025)	(0.038)	(0.008)	(0.031)	(0.040)	(0.009)	(0.035)
Settlement time	-0.079*	-0.000	-0.085*	-0.073*	0.000	-0.075*	-0.075	0.002	-0.083	-0.051	0.002	-0.063
	(0.046)	(0.010)	(0.046)	(0.043)	(0.011)	(0.043)	(0.054)	(0.010)	(0.051)	(0.058)	(0.011)	(0.056)
Prop. Cash settlement	0.020	0.009	-0.080	-0.001	0.008	-0.114	0.025	0.007	-0.045	-0.011	0.012	-0.111
	(0.148)	(0.024)	(0.102)	(0.141)	(0.026)	(0.110)	(0.151)	(0.023)	(0.102)	(0.138)	(0.025)	(0.100)
Ins. payment* Settlement time	-0.008**	-0.001	-0.009***	-0.008**	-0.001	-0.009***	-0.008*	-0.000	-0.009**	-0.001	-0.001	-0.007*
	(0.003)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)	(0.004)	(0.001)	(0.004)	(0.005)	(0.001)	(0.004)
Ins. payment* Prop. Cash settled	-0.005	-0.000	0.004	-0.004	-0.000	0.006	-0.004	-0.000	0.002	-0.003	-0.001	0.006
	(0.013)	(0.002)	(0.009)	(0.012)	(0.003)	(0.009)	(0.013)	(0.002)	(0.009)	(0.012)	(0.003)	(0.008)
Indirect effect												
Insurance payment	0.009	0.006**	0.015	0.019	0.014**	0.032				0.137*	0.041	0.165**
	(0.013)	(0.002)	(0.011)	(0.032)	(0.006)	(0.025)				(0.077)	(0.038)	(0.075)
Settlement time	-0.012	-0.000	-0.003	-0.020	-0.001	0.003				-0.176	-0.028	-0.175
	(0.011)	(0.003)	(0.009)	(0.028)	(0.007)	(0.022)				(0.107)	(0.053)	(0.112)
Prop. Cash settlement	0.060	0.007	-0.006	0.102	0.017	-0.067				-0.360	0.028	-0.610*
	(0.097)	(0.020)	(0.075)	(0.240)	(0.054)	(0.182)				(0.340)	(0.117)	(0.355)

Ins. payment* Settlement time	-0.003	-0.001*	-0.003*	-0.005	-0.002	-0.005*				-0.017**	-0.006	-0.018**
	(0.002)	(0.000)	(0.001)	(0.003)	(0.001)	(0.003)				(0.008)	(0.006)	(0.008)
Ins. payment* Prop. Cash settled	-0.008	-0.000	-0.002	-0.016	-0.001	-0.001				0.016	-0.001	0.039
	(0.008)	(0.002)	(0.006)	(0.023)	(0.006)	(0.016)				(0.028)	(0.013)	(0.029)
Total effect of Ins. payment	0.069	0.012	0.112**	0.101	0.022	0.171**	-0.007	0.004	0.006	0.034	0.021	0.085
	(0.061)	(0.015)	(0.048)	(0.088)	(0.026)	(0.077)	(0.048)	(0.009)	(0.042)	(0.098)	(0.048)	(0.101)

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. All regressions are estimated with AU and quarter fixed effect.

Table 4-101a Economic recovery following the earthquakes – Spatial panel AU and quarter fixed effects

	Dependent variable: Quarterly change in night-time light								
VARIABLES	**SAR**			**SAC**			**SEM**		
	Building	**Land**	**Total**	**Building**	**Land**	**Total**	**Building**	**Land**	**Total**
Main									
Insurance payment	0.046	0.007	0.064**	0.042	0.007	0.055**	0.050	0.004	0.065**
	(0.032)	(0.008)	(0.026)	(0.028)	(0.008)	(0.023)	(0.038)	(0.008)	(0.031)
Settlement time	-0.074	0.000	-0.080*	-0.063	0.000	-0.065	-0.075	0.002	-0.083
	(0.045)	(0.010)	(0.045)	(0.040)	(0.010)	(0.039)	(0.054)	(0.010)	(0.051)
Prop. Cash settlement	0.019	0.008	-0.077	-0.000	0.006	-0.100	0.025	0.007	-0.045
	(0.141)	(0.024)	(0.099)	(0.125)	(0.023)	(0.097)	(0.151)	(0.023)	(0.102)
Ins. payment* Settlement time	-0.008**	-0.001	-0.009***	-0.007**	-0.001	-0.007***	-0.008*	-0.000	-0.009**
	(0.003)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)	(0.004)	(0.001)	(0.004)

Ins. payment* Prop. Cash	-0.005	-0.000	0.003	-0.004	0.000	0.005	-0.004	-0.000	0.002
Settlement	(0.012)	(0.003)	(0.008)	(0.011)	(0.002)	(0.008)	(0.013)	(0.002)	(0.009)
Spatial									
ρ	0.464***	0.467***	0.464***	0.664***	0.673***	0.675***			
	(0.041)	(0.041)	(0.041)	(0.074)	(0.070)	(0.068)			
λ				-0.338**	-0.345**	-0.357***	0.462***	0.465***	0.461***
				(0.144)	(0.138)	(0.137)	(0.041)	(0.041)	(0.041)
Observation	2686	2686	2686	2686	2686	2686	2686	2686	2686
N.o Area Units	158	158	158	158	158	158	158	158	158
R-squared	0.706	0.705	0.706	0.706	0.704	0.705	0.705	0.705	0.707
Hausman chi-sq	185.7	183.6	170.3				165.3	199.	171.8

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. Rho ρ is the spatial autoregressive coefficient and Lambda λ is the spatial autocorrelation coefficient. All regressions are estimated with AU and quarter fixed effect.

Table 4-11b Economic recovery following the earthquakes – Spatial panel AU and quarter fixed effects

VARIABLES	SDM		
	Building	Land	Total
Main			
Insurance payment	0.024	0.045	0.024
	(0.042)	(0.036)	(0.042)
Settlement time	-0.038	-0.050	-0.038
	(0.062)	(0.059)	(0.062)
Prop. Cash settlement	0.011	-0.074	0.011
	(0.140)	(0.099)	(0.140)
	0.001	0.001	0.001
Ins. payment* Settlement time	(0.005)	(0.005)	(0.005)
	-0.004	0.004	-0.004
Ins. payment* Prop. Cash	(0.012)	(0.008)	(0.012)
Wx			
Insurance payment	0.072	0.079	0.072
	(0.056)	(0.050)	(0.056)
Settlement time	-0.088	-0.082	-0.088
	(0.077)	(0.075)	(0.077)
Prop. Cash settlement	-0.224	-0.334	-0.224
	(0.236)	(0.220)	(0.236)
	-0.001	-0.001	-0.001
Ins. payment* Settlement time	(0.006)	(0.006)	(0.006)
	0.012	0.022	0.012
Ins. payment* Prop. Cash	(0.019)	(0.018)	(0.019)
Spatial			
ρ	0.462***	0.461***	0.462***
	(0.041)	(0.041)	(0.041)
Observation	2686	2686	2686
N.o Area Units	158	158	158
R-squared	0.706	0.707	0.708
Hausman chi-sq	243.6	199.2	223.9

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. Wx is the spillover effect coefficients and Rho ρ is the spatial autoregressive coefficient. All regressions are estimated with AU and quarter fixed effect. All models have Hausman *p*-value equal to zero.

Table 4-12 Economic recovery following the earthquakes – Direct and indirect effects (Inverse distance matrix)

VARIABLES	Dependent variable: Quarterly change in night-time light											
	SAR			SAC			SEM			SDM		
	Building	Land	Total	Building	Land	Total	Building	Land	Total	Building	Land	Total
Direct effect												
Insurance payment	0.072* (0.037)	0.009 (0.009)	0.095*** (0.030)	0.070* (0.031)	0.009 (0.009)	0.090*** (0.025)	0.071* (0.038)	0.009 (0.009)	0.094*** (0.031)	0.067* (0.037)	0.007 (0.009)	0.091*** (0.031)
Settlement time	-0.114** (0.056)	0.001 (0.011)	-0.122** (0.052)	-0.111** (0.052)	0.001 (0.009)	-0.113** (0.042)	-0.112* (0.058)	0.001 (0.012)	-0.120** (0.054)	-0.107* (0.056)	0.004 (0.011)	-0.117** (0.053)
Prop. Cash settlement	0.017 (0.156)	0.012 (0.027)	-0.110 (0.123)	0.010 (0.153)	0.012 (0.025)	-0.114 (0.128)	0.017 (0.156)	0.012 (0.028)	-0.110 (0.124)	0.019 (0.156)	0.010 (0.027)	-0.108 (0.125)
Ins. payment* Settlement time	-0.012*** (0.004)	-0.001 (0.001)	-0.013*** (0.003)	-0.012*** (0.004)	-0.001 (0.001)	-0.013*** (0.003)	-0.011*** (0.004)	-0.001 (0.001)	-0.013*** (0.003)	-0.011*** (0.004)	-0.001 (0.001)	-0.013*** (0.003)
Ins. payment* Prop. Cash settled	-0.007 (0.013)	-0.000 (0.003)	0.005 (0.010)	-0.005 (0.013)	-0.000 (0.003)	0.005 (0.009)	-0.007 (0.014)	-0.000 (0.003)	0.005 (0.010)	-0.007 (0.013)	0.000 (0.003)	0.004 (0.010)
Indirect effect												
Insurance payment	0.002 (0.012)	0.000 (0.002)	0.003 (0.014)	0.005 (0.024)	0.002 (0.004)	0.006 (0.025)				0.181 (0.145)	0.154 (0.097)	0.187 (0.146)
Settlement time	-0.004 (0.018)	-0.000 (0.002)	-0.004 (0.019)	-0.004 (0.018)	-0.000 (0.002)	-0.004 (0.019)				0.373 (0.238)	0.222** (0.101)	0.365 (0.233)
Prop. Cash settlement	0.002 (0.025)	0.000 (0.004)	-0.003 (0.025)	0.002 (0.022)	0.000 (0.002)	-0.001 (0.020)				-0.138 (0.538)	0.161 (0.537)	-0.042 (0.606)

Ins. payment* Settlement time	-0.000 (0.002)	0.000 (0.000)	0.000 (0.002)	-0.000 (0.002)	0.000 (0.000)	0.000 (0.002)				-0.029 (0.018)	-0.019* (0.010)	-0.028* (0.017)
Ins. payment* Prop. Cash settled	-0.000 (0.002)	-0.000 (0.000)	0.000 (0.002)	-0.000 (0.001)	-0.000 (0.000)	0.000 (0.003)				0.012 (0.043)	-0.021 (0.059)	0.004 (0.049)
Total effect of Ins. payment	-0.012 (0.050)	0.007 (0.012)	0.008 (0.044)	-0.010 (0.321)	0.008 (0.010)	0.013 (0.033)	-0.009 (0.048)	0.006 (0.010)	0.011 (0.038)	-0.002 (0.208)	0.094 (0.108)	0.002 (0.209)

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. All regressions are estimated with AU and quarter fixed effect.

Table 4-13 Economic recovery following the earthquakes – AU and monthly fixed effects

VARIABLES	Dependent variable: Monthly change in night-time light		
	Building	Land	Total
Insurance payment	0.189 (0.149)	-0.067** (0.031)	0.179 (0.141)
Settlement time	-0.646 (0.566)	0.055 (0.079)	-0.565 (0.525)
Prop. Cash settlement	-0.361* (0.213)	-0.0670 (0.178)	0.469** (0.235)
Ins. payment* Settlement time	-0.044 (.132)	0.005 (0.017)	-0.028 (0.124)
Ins. payment* Settlement time	0.034 (.132)	0.002 (0.027)	0.024 (0.094)
Constant	1.714*** (0.617)	1.631*** (0.111)	1.880*** (0.638)
Observation	8216	8216	8216
N.o Area Units	158	158	158
R-squared	0.946	0.946	0.946
Total effect of Ins. payment	0.076 (1.041)	0.042 (0.066)	0.011 (0.846)

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. All regressions are estimated with AU and monthly fixed effect

Table 4-14 Economic recovery following the earthquakes – Using Property value as Instrument variable

VARIABLES	Dependent variable: Monthly change in night-time light		
	Building	Land	Total
Insurance payment	1.006*	0.035	1.815
	(0.586)	(0.169)	(1.708)
Settlement time	-1.371*	-0.028	-2.564
	(0.789)	(0.181)	(2.425)
Prop. Cash settlement	-1.460	0.000	-2.594
	(0.931)	(0.082)	(2.469)
Ins. payment* Settlement time	-0.012*	-0.000	-0.022
	(0.007)	(0.002)	(0.021)
Ins. payment* Settlement time	0.129	0.001	0.221
	(0.085)	(0.007)	(0.215)
Constant	11.101*	0.097	20.796
	(6.539)	(1.288)	(19.790)
Observation	2686	2686	2686
N.o Area Units	158	158	158
R-squared	0.456	0.378	0.485
Total effect of Ins. payment	1.032*	-0.351**	1.832
	(0.592)	(0.169)	(1.724)

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. AU cluster - robust standard errors are shown in parentheses. All regressions are estimated with AU and monthly fixed effect

Appendix Figure

Figure 4-9 Tree diagram for extracting nightlight intensity (Model Builder – ArcGIS)

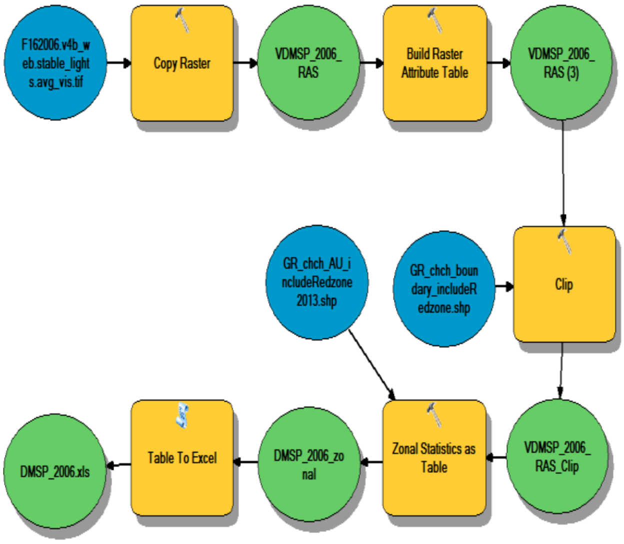


Figure 4-10 Macro-seismic intensity map of the 2011 February earthquake

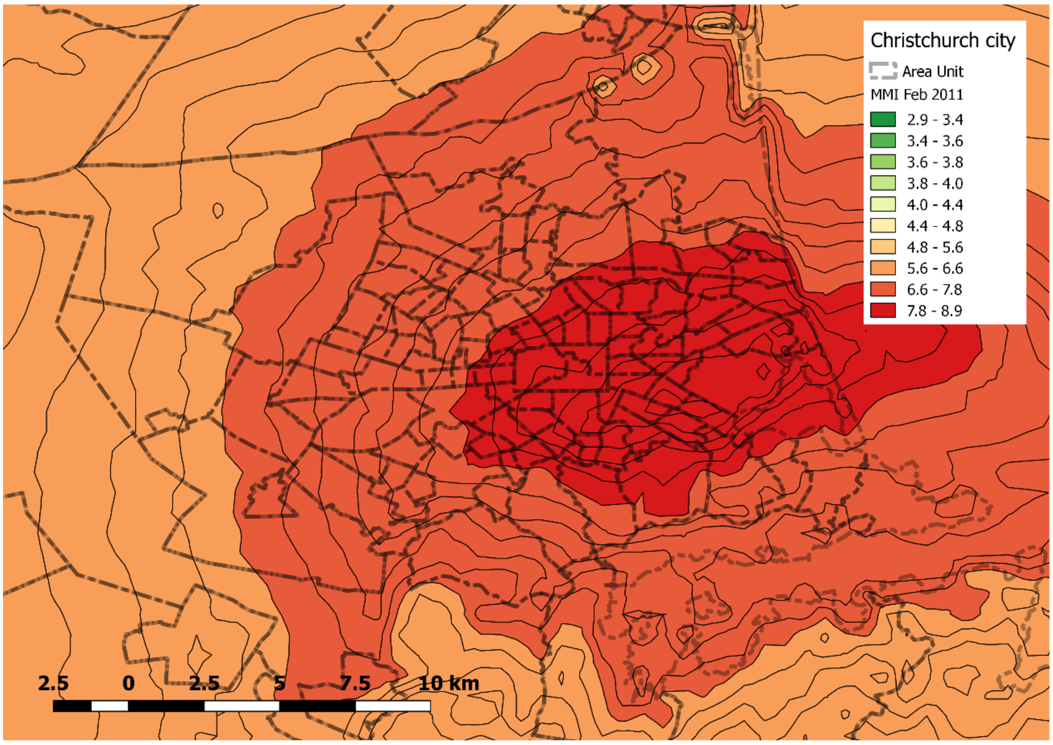


Figure 4-11 Average annual nightlight DMSP/OLS for area units in Christchurch

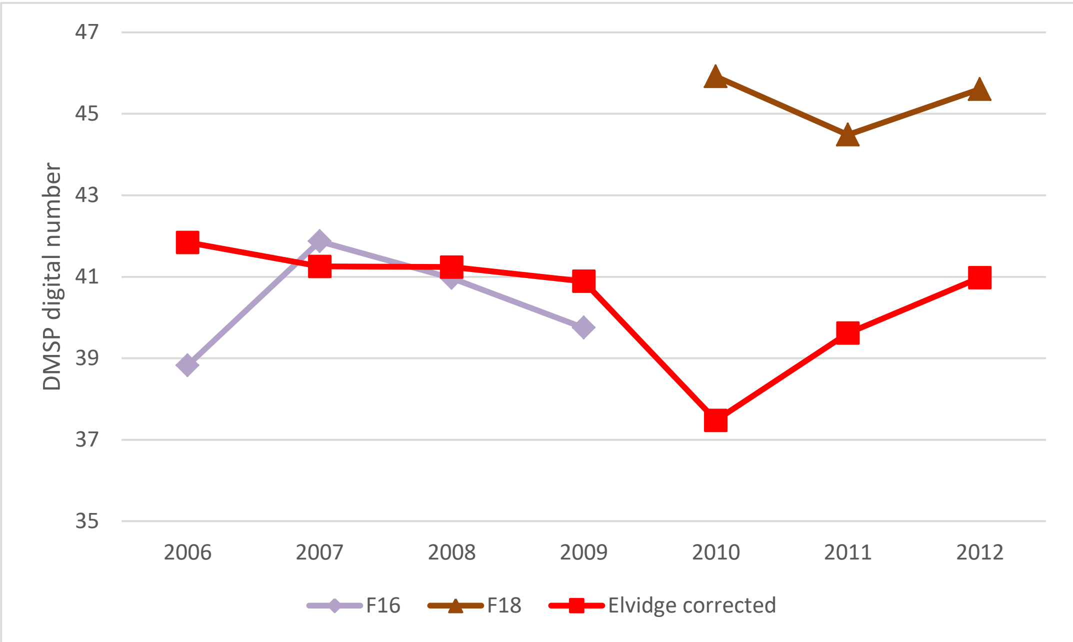
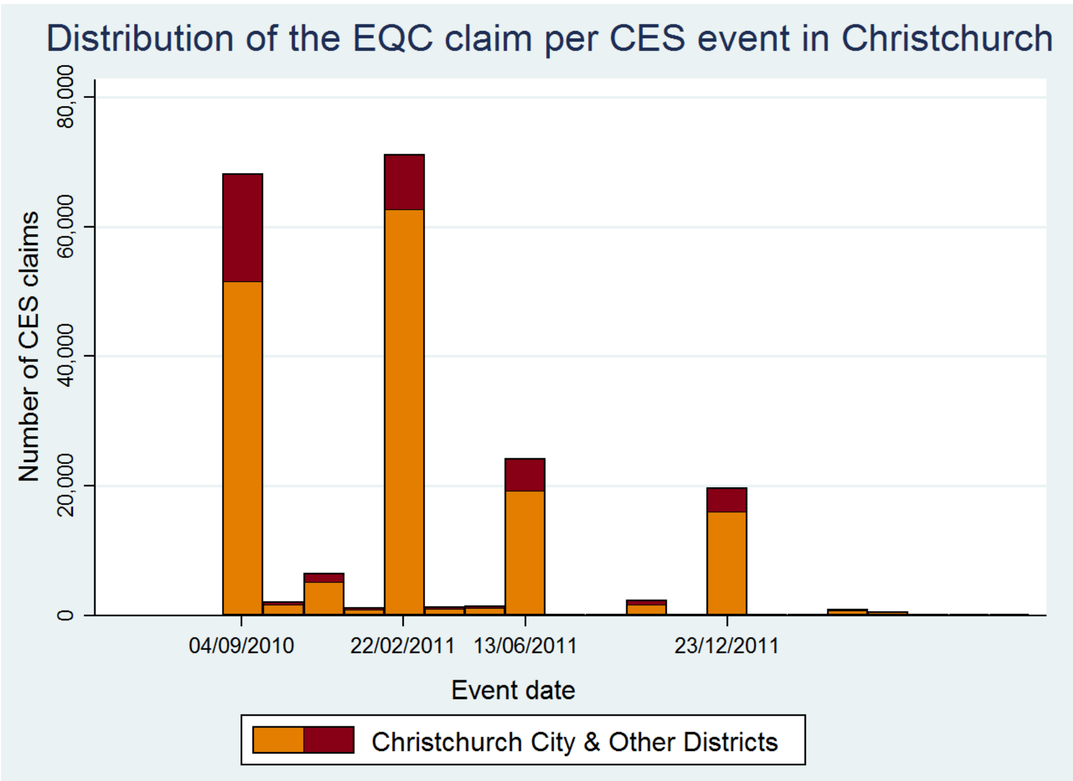


Figure 4-12 Histogram of residential claims for different earthquake events



Chapter 5

Homeowners’ choice when the government buys you out

Abstract

After the Christchurch earthquakes, the New Zealand government declared about 8000 houses as Red Zoned, prohibiting further developments in these properties, and offering the owners to buy them out. The government provided two options for owners: the first was full payment for both land and dwelling at the 2007 property evaluation, the second was payment for land, and the rest to be paid by the owner’s insurance. Most people chose the second option. Using data from Land Information New Zealand, combined with data from Statistics New Zealand, this project empirically investigates what determined homeowners’ choices, and how peer effect may have influenced this choice and may have led to sub-optimal outcomes.

5.1. Introduction

Household choices have been extensively examined in various economic contexts, including labor market behavior (Fogli & Veldkamp, 2011; Knowles, 2013), consumption smoothing (Lokshin & Yemtsov, 2004; Post & Hanewald, 2013) and fertility choices (Galor & Moav, 2002; Hazan & Zoabi, 2006). However, household decision making in other areas is less understood. Specifically, there is no previous study regarding the household choice in home buyout programs post disaster.

This topic is important for policy decision making. Property acquisition programs are increasingly used to encourage homeowners to relocate permanently out of hazardous areas post disaster. Binder and Greer (2016) analyze the design of a buyout program in Oakwood beach, New York after Hurricane Sandy and compared it with previous cases in the US. The authors conclude the program improves the experience of participating households, but argue for greater transparency at the implementing stage. In addition, Green and Olshansky (2012) claim that the home buyout program post-Hurricane Katrina and Rita was complicated and difficult for participants to follow, combined with financial disincentives and restrictions. This home relocation policy, it may be argued, prolonged the recovery process and caused further economic and social inequalities post-events (Gotham, 2014). Therefore, any insights about disaster compensation and relocation programs by governments are valuable for pre-event planning for post-disaster recovery.[111]

[111] The World Bank analyses the relocation and reconstruction process in affected communities (Sendai, Ishinomaki and Natori cities) after the 2011 Great East Japan Earthquake. Japanese government offers voluntary relocation schemes that provide options to allow communities staying together and decide their desired resettlement location. (Ranghieri & Ishiwatari, 2014)

In this paper, we aim to investigate the drivers of homeowner's decisions regarding financial offer options in the buyout process, as carried out by the government. Generally, we expect that household choice will be dependent on the benefits and costs of available options. But we also find that individual's decisions are also influenced by her surrounding neighborhood's choice and characteristics.

In the behavioral economics literature, social influence describes how an individual responds to information acquired from her peers (Munshi & Myaux, 2006). Peer pressure occurs when she acts in a similar way to her group in order to avoid social conflict (Kohler et al., 2001). In addition, Bramoullé et al. (2009) observe that networks encourage people to copy their peers' behavior, based on their identity.

However, although the social interactions (peer effects) theories are frequently described, their empirical identification and quantification are difficult (Manski 1993; Manski, 2000; Moffitt, 2001; Bursztyn et al., 2014). Feld and Zolitz (2017) identify different channels of peer effects using placebo setting to correct for mechanical bias. Utilizing developments in spatial econometrics, we identify peer effects as spatial dependence among households (Lee, 2007; Chakir & Parent, 2009; Smirnov, 2010; Calabrese & Elkink, 2014). By doing that, we are able to account for the interdependency among households and their related characteristics and preferences.

This study will examine in detail one instance of an acquisition program, the one that was implemented in the city of Christchurch in New Zealand, after the catastrophic earthquake of February 22nd, 2011. This is the Residential Red Zone (RRZ) program that ultimately led to about 8000 households being permanently relocated away from their previous homes.

The remainder of the paper is organized as follows. In Section 2, we briefly describe the events that led to the development of the zoning and relocation policy in Christchurch, but do not discuss the political process that led to this decision. The focus here is on describing the financial decision-making by the homeowners that were forced to abandon their homes in the area that was declared 'red-zoned' (i.e., no longer suitable for residential habitation). Section 3 describes and analyzes the datasets that we use in the paper. In Section 4, we introduce the chosen estimation methods including binary choice model and spatial dependence model. The estimation results are presented in Section 5, followed by our conclusion and remarks in Section 6.

5.2. The Earthquake and Red Zoning

A sequence of earthquakes hit the Canterbury region of the South Island of New Zealand, in 2010-2012. The initial September 2010 earthquake caused significant damage south-east of the city of Christchurch, but a shallower aftershock in February 2011, one whose epicentre was closer to the city centre, caused extensive damage to residential properties all over Greater Christchurch and damaged almost all commercial buildings in the city centre. 185 people died in this event, more than half in the collapse of a single office building. The earthquakes generated particularly severe damage to residential housing and land in the eastern suburbs of Christchurch. In some affected areas, seismically induced liquefaction affected the land significantly, making it potentially untenable. Many properties encountered issues related to underground sewerage and water supply systems which made them very difficult to live in. For instance, some residential areas suffered from jets of contaminated water or sand and silt that welled up into gardens or even houses. In other areas, properties that did not suffer much earthquake damage became exposed to high risk of rock falls, cliff collapses and landslides.

As a result, in June 2011, the government announced an emergency policy response for residential areas that had area-wide damage and/or changed risks to human life. After a lengthy process of geotechnical investigations and consultations, the Crown decided to categorize some areas as Residential Red Zones (RRZ). The criterion used for defining the RRZ flat-land areas (where the vast majority of RRZ properties were located) were: significant and extensive area-wide land damage, in which success of engineering solutions for land remediation may be uncertain in terms of the design, its costs, and the possibility of delays to the start of work due to ongoing aftershocks (Saunders & S.Becker, 2015).

The Crown initially offered to purchase only insured RRZ properties at their assessed market value in 2007 (McDonald & Carlton, 2016). [112] More than 95% of RRZ properties were insured. Eventually, the Crown was forced by the courts to extend similar offers to uninsured properties and to owners of undeveloped land (which is not insurable in New Zealand).

The Crown provided two options for RRZ property owners to choose from when accepting the offer to transfer title of the land to the Crown. In the first option, homeowners could sell their property including the land and improvements (buildings and fixtures) based on the 2007 rating valuation (of both land and improvements – these are evaluated separately in New Zealand). By the doing that, the owners were providing the Crown the entitlement to any insurance claim they may have pending against their insurer for earthquake damage. Henceforth, we will term this the 'Crown option'. For the second option, the property owners would sell only their land

[112] The choice of 2007 was deliberate. Assessments, required for the collection of property taxes, are done every three years, so in principle the 2010 values could have been used. However, the property market in New Zealand, as elsewhere, experienced some decline after the Global Financial Crisis, which started in September 2008 with the collapse of Lehmann Brothers.

to the government at the 2007 rating valuation of the land, and they would maintain any insurance claim they may have against their insurer for damage to the dwelling that sits on that land. Here, we call this the 'Insurance option'.

5.3. Data

We focus only on the properties that accepted the offer to sell the property, as only a very small number of owners did not accept and chose to remain in the RRZ.[113] The information about these properties was recorded in the RRZ settlement database maintained by Land Information New Zealand (LINZ). The data contains information about 7,428 properties located in the RRZ.[114] There are 1,694 homeowners who chose the Crown option and 5,788 who decided to accept the Insurance option.

Figure 5-1 represents the aggregated payment by the government and insurers for each option. The total Crown's spending for the RRZ purchase which contains the Crown option's total payment ($355 million + $235 million) and the Insurance option's land payment ($983 million). These sum up to a total cost for the Crown of $1.57 billion, but a significant portion of that was later recouped from the public insurer (EQC) and private insurers. The Crown receives the insurance claim payments for Crown option's properties. Hence, the net government payment is around $1.29 billion. Using the EQC claim data, we estimate that EQC and insurers expected to pay $ 1.06 billion to resolve the building structure damages for the Insurance option.[115]

[113] As of July 2018, less than 30 properties in the RRZ were still occupied. The RRZ program was always framed as voluntary, so in principle owners could have chosen to stay, but by staying they forfeited on the Crown's offer to buy their property.

[114] In total, there were 8,060 residential properties located in the RRZ; the records for other properties, except for the 30 or so that did not settle with the crown, are most likely associated with vacant land properties or properties with very low-worth assets on them – i.e., not houses (Nielsen, 2016).

[115] Insurers assessed and recorded the damage cost for each individual property affected by the earthquakes. We aggregate the compensation amount for the RRZ's properties.

Figure 5-1 Aggregated RRZ payment between two options

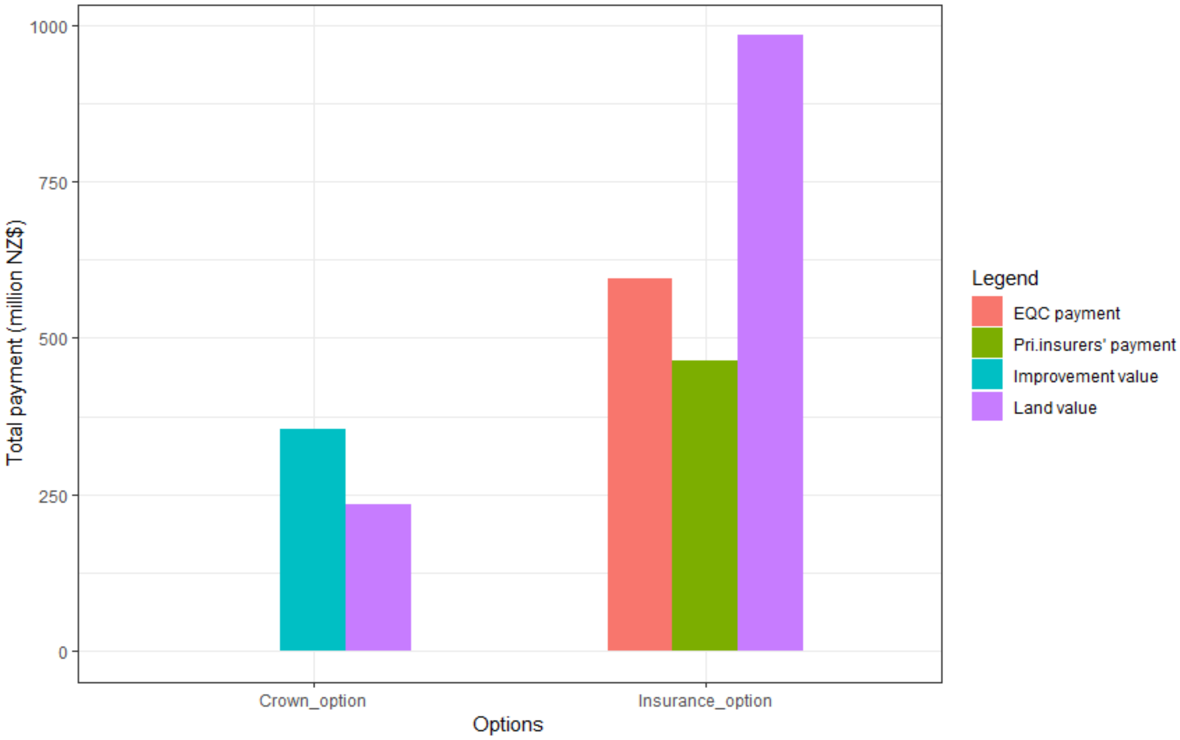
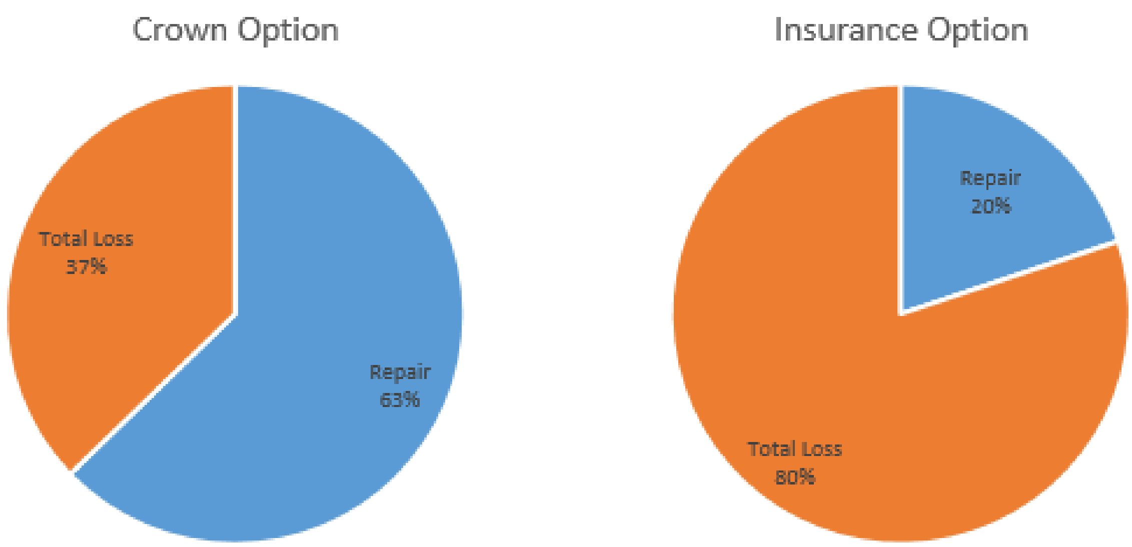


Figure 5-2 Comparison of damage status between two options



RRZ houses were assessed for damage status by insurance assessors and engineers. Figure 5-2 illustrates the proportion of damage status (repair or total loss) of the two offer options. Not surprisingly, the properties whose homeowners chose the Crown option, on average experienced less damage. This is expected as those owners whose homes were not defined as total loss would not have received full compensation if they had gone with the other (Insurance) option. In contrast, 80 percent of Insurance option properties had been identified as "total loss".[116] We expect that the more these owners can claim from insurance, the more they are likely to pursue the Insurance option. In particular, as most insurance contracts in NZ at the time stipulated that insurers should pay for the complete reconstruction of a house, rather than based on a capped sum-insured (Nguyen & Noy, 2019). That means that the liability of the insurer was typically larger than the market value of the house if the house damage was such that it required complete reconstruction. The group of owners (37% of the Crown option) who did experience total loss, but still chose to go with the Crown option, probably chose so as it was a much simpler, certain, and quick than choosing the Insurance option and negotiating with insurance about the hypothetical cost of rebuilding. The one group that is more puzzling is the 20% of the Insurance option (1206 properties) that were assessed not to have suffered a total loss. It is expected that in this case the owners would be compensated less with this Insurance option than they would have had, had they chose the Crown option.[117]

[116] Alternatively, we have the earthquake damage ratio at mesh-block (MB)[116] level, constructed using the EQC claim data (Nguyen & Noy, 2019). The average damage ratio of Crown option's property is 18.6% while the damage ratio is 20.6% for Insurance option's property.

[117] We do not know the reasons for this choice. Maybe implausibly, it might be the case that insurers preferred negotiating with owners than with the Crown, and therefore made more generous offers to these owners.

We also compare the building structure damage cost and the improvement value for the two options. In the Crown option, the total improvement value (IV) is higher than the total dwelling damage from EQC claim data by $70 million, while we find the opposite result for the properties' payments in the Insurance option. The dwelling damage is $50 million higher than the improvement value.

Table 5-1 provides the summary statistics of the property-level information in different samples. In the dataset, we have filtered out properties that have value less than $30,000 or their building floor is less than 15 m^2 as they are likely not residential houses. We are then left with 7,482 observations. 93 percent of the affected properties are located in the RRZ Flat land (Christchurch and Waimakariri to the north of the city), and only 502 houses in the Port Hills red-zoned areas.[118] The location of the RRZ areas are shown in Figure 5-3.

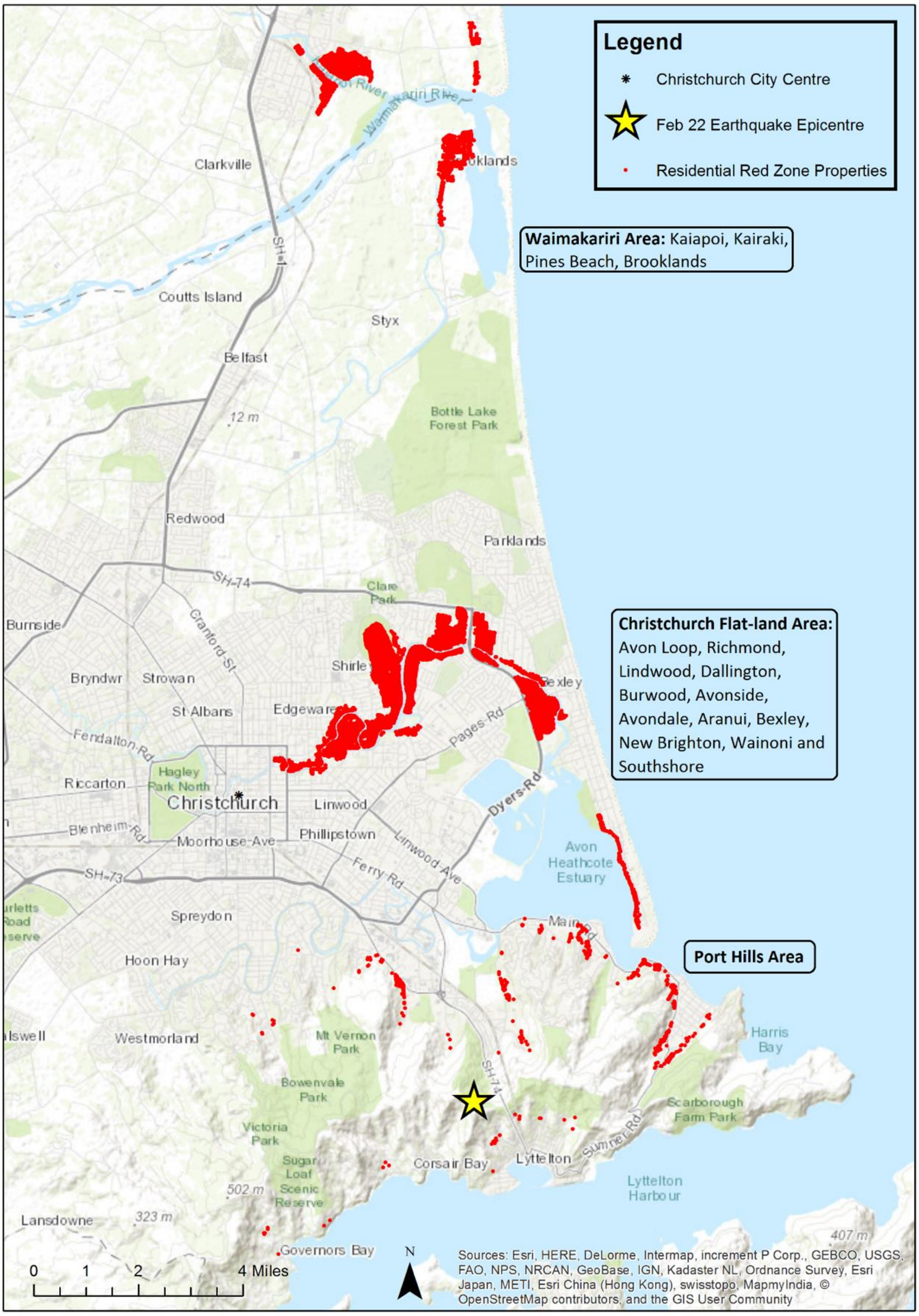
[118] The flat-land areas were declared a Red Zone because of liquefaction experienced during the earthquake (and couldn't not be ameliorated), or because of heightened future liquefaction risk. The Port Hills areas were declared Red Zoned because of heightened risk of rockfall from the surrounding cliffsides. The flat land red zones contain Kaiapoi town, coastal suburbs of Pines Beach, Kairaki, Brooklands and suburbs around the Avon-Otakaro River and by sea. The Port Hills red zones are located in the fringe of the hills. The area contains parts of Hillsborough, Heathcote, Redcliffs, Sumner, Scarborough, Lyttelton and Governros Bay.

Table 5-1 Comparison of the selected variable per-property means for different sub-samples

	Christchurch Flat-land	Waikamariri Flat-land	Port Hills	Other areas in Chch.	Crown Option	Insurance Option
Improvement val. ($)	190,416	175,540	309,986	238,263	209,453	195,272
	(209,526)	(88,799)	(291,220)	(215,058)	(105,590)	(222,625)
Land value ($)	153,971	147,738	229,586	119,928	139,143	163,375
	(76,088)	(43,171)	(191,743)	(93,164)	(68,389)	(90,593)
Bldg floor area (sqm)	137.4	153.3	209.9	148.5	137.4	147.5
	(140.8)	(91.1)	(181.3)	(162.2)	(60.4)	(152.8)
Estimated damage ($)	192,429	173,010	204,942	54,214	166,940	201,311
	(109,901)	(128,642)	(261,258)	(42,973)	(114,725)	(136,437)
Damage status (%)	73.6	68.1	40.8	NA	37.2	80.1
	(44.0)	(46.6)	(49.2)		(48.3)	(39.9)
Damage ratio (%)	20.7	20.5	14.1	9.3	18.6	20.7
	(13.6)	(16.5)	(14.5)	(7.8)	(14.6)	(14.3)
2/2011 eq intensity	8.3	6.8	7.7	3.9	8.1	8.1
	(0.2)	(0.2)	(0.3)	(0.8)	(0.6)	(0.6)
NZ Deprivation index	5.0	4.2	2.7	5.5	5.0	4.6
	(2.1)	(2.1)	(1.5)	(3.8)	(2.1)	(2.1)
Observations	5,592	1,388	502	159,607	1,694	5,788

Data are from LINZ, EQC, USGS and StatisticsNZ at property level, except earthquake intensity and NZ deprivation index which are available at Meshblock level. The standard deviation is given in parentheses.

Figure 5-3 Residential Red Zone properties – East side of Christchurch city



Overall, the improvement value and land value of a typical RRZ residential property are $200,000 and $158,000, respectively. The average RRZ house value is slightly lower than the average property value of other areas in the Greater Christchurch region ($358,191). There are also differences in mean property values for the different RRZ areas. Properties in the Christchurch flat-land have somewhat higher value, on average, compared to houses in Waimakariri. However, properties in the RRZ Port Hills were worth twice as much as in other RRZ areas. The dwellings were also larger with 210 m^2 of building floor area, while houses in the flat land areas were around 140-150 m^2. Regarding the earthquake damage, 70 percent of RRZ properties have been identified as "total loss". Most RRZ properties located in areas that experienced a Modified Mercalli Intensity of 8 (defined as 'Severe'[119]) from the 22/2/2011 earthquake. And based on the EQC claim data, the average damage to value ratio[120] of these properties is approximately 50 percent.[121] In contrast, other areas in Christchurch experience much less earthquake damage. On average, the earthquake intensity is 3.9 in MMI scale and the damage ratio is 9.3%.

Using the three damage indicators, the premises in the RRZ Christchurch flat-land suffered most from the earthquake (53.7 percent), while the Port Hills houses experienced much less damage (24.9 percent). In fact, some houses, in the Port Hills RRZ especially, were not affected by any earthquake damage. They were red zoned due to the unacceptable life risk of rock fall and cliff collapse. In our estimations, we also include the New Zealand Socioeconomic Deprivation Index (pre-earthquakes) obtained from the 2006 NZ Census.[122]

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[119] According to USGS, the level 8 of Modified Mercalli intensity is described as "Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned."

[120] The damage to value ratio is calculated as the amount of assessed building damage over the 2010 improvement value of the affected properties in each MB.

[121] This ratio assumes that the land damage ratio for properties in the RRZ is 100%.

[122] The NZ Deprivation Index is the principle component obtained from 8 variables (income, home ownership, government support, employment, qualifications, living space, communication, and transport) (Salmond et al., 2007).

The households in RRZ Christchurch and Waikamariri flat-land were not as wealthy as families who lived in the Port Hills. The difference in the deprivation index between RRZ Christchurch and Port Hills areas is about 1.5 points (out of 10).

In Table 5-1, we also compare the statistics for the two options (the Crown and Insurance options). We observe that the Crown option houses have higher improvement value while the Insurance option properties have higher land value. However, the difference is small. As suggested previously, the mean of the damage indicator suggests that households who chose the Insurance option experienced more earthquake damage. They have slightly larger dwelling and live in less deprived areas, compared to the Crown option's homeowners. This difference is interesting, from the perspective of this paper, as it suggests there is public interest in intervening in a managed-retreat program even if the risk is insured, as low-income households are less likely to be able to access the full benefits of insurance (see also Owen and Noy (2017)).

Table 5-2 compares the household characteristics between the two groups using the 2006 Census demographic variables (at every meshblock[123]). There is no statistically significant difference in the mean of demographic variables between the two options.

[123] A meshblock is the smallest geographic area, defined by Statistics New Zealand. Its size can vary from a city block to a large plot of rural land.

Table 5-2 Summary statistics of household characteristics

	Crown option's mean	Insurance option's mean
Proportion of Elderly (age>65) (%)	15.44	16.42
	(9.77)	(15.04)
Proportion of Maori descent (%)	9.73	9.85
	(5.79)	(5.95)
Proportion of House ownership (%)	67.56	69.04
	(15.53)	(13.19)
Proportion of Higher education (%)	12.00	11.74
	(8.31)	(7.77)
Proportion of Fulltime (%)	50.64	49.23
	(9.77)	(11.24)
Family Income ($)	50,434	50,660
	(15,869)	(15,280)
Proportion of Single parent (%)	16.15	16.00
	(10.01)	(9.61)

Data are from the 2006 Stats NZ Census at meshblock level. Standard deviation is given in parentheses.

5.4. Methodology

We investigate the homeowner's choice regarding the Crown offer, using several econometric specifications. We start with a limited dependent variable (Probit) regression model:

$$\Pr(Option_i = 1|x_i) = F(\alpha + \beta_1\, propvalue_i + \beta_2\, eqdamage_i + \beta_k FE_{MB}) \qquad \text{(Probit)}$$

The dependent variable $Option_i$ is a binary variable which takes value of 0 if homeowner chose the Crown option and value of 1 for the Insurance option. Therefore, we estimate the probability of homeowner (i) choosing the Insurance option. The vector of explanatory variables includes the property value (improvement and land) and the earthquake damage indicator, for which we use the binary variable damage status for each property (repair or total loss), provided by LINZ.[124] In addition, we also include mesh-block fixed-effects in order to capture unobserved variations across MBs. The vector β is the set of coefficients relating to the impact of changes in the estimated probability. The function $F(\cdot)$ represents the cumulative distribution function of the standard normal distribution.[125]

In our main specifications, we examine whether there are spatial effects; i.e., are homeowner's decisions similar in certain RRZ neighborhoods. Using the optimized hotspot analysis toolbox in ArcGIS, Figure 5-4 identifies clusters of properties for which owners were choosing either the Crown option (blue) or the Insurance option (red) [126]. The value of Moran's I is 0.11; indicating that the spatial effect is statistically significant.

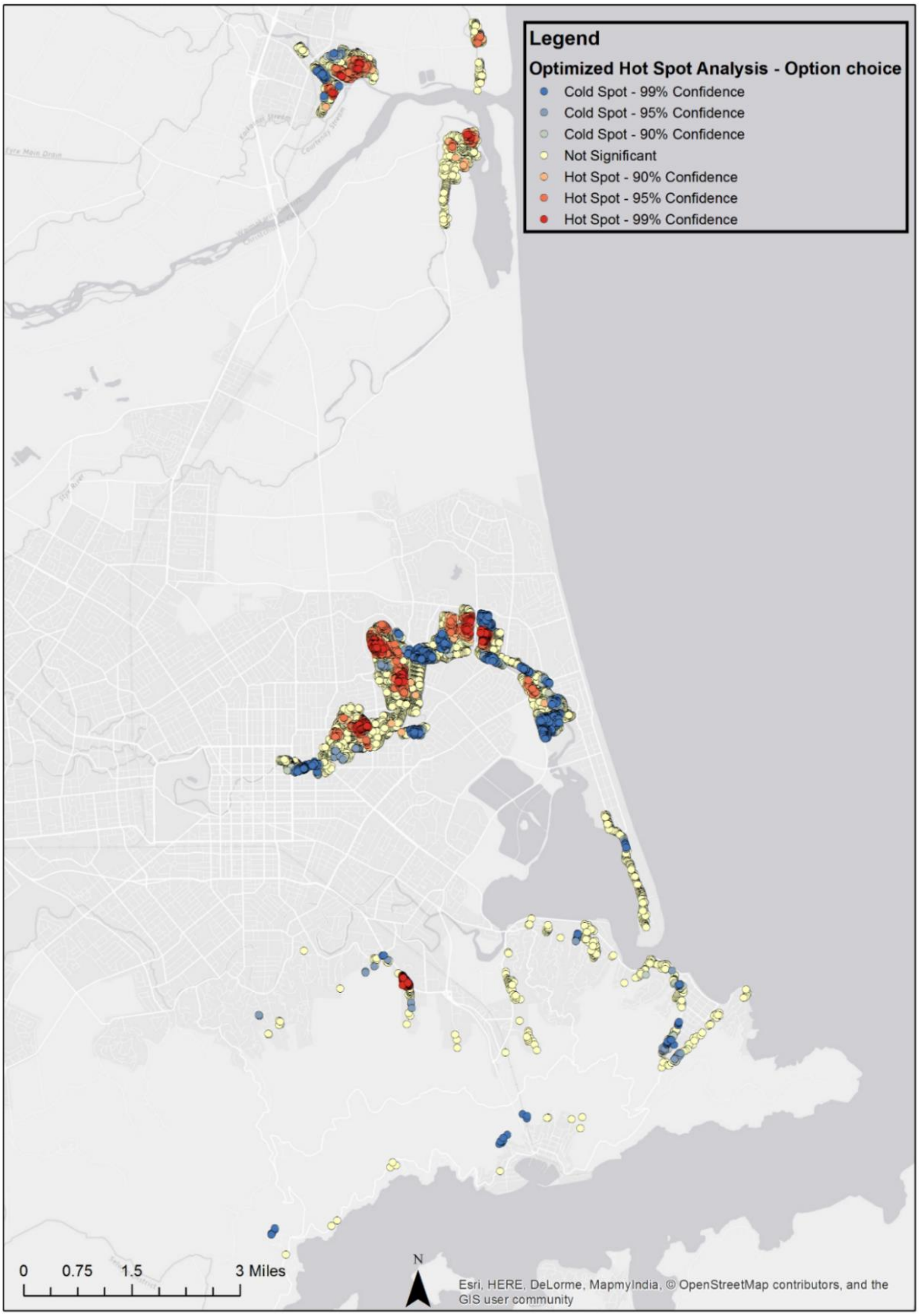
In other words, we control for how the homeowners' decision is influenced by the decision of their neighbors by estimating a set of spatial regression models. Spatial analysis methods have been used more frequently in economics and regional science (Kelejian & Piras, 2014; Nguyen & Noy, 2018a; Taupo et al., 2018) This spatial regression models allow us to obtain the spillover effect from neighboring households (Anselin et al., 2008; Lee & Yu, 2010).

[124] In results provided in the appendix, we also use the earthquake damage ratio at MB level, as described in the previous section. Alternatively, we have used the 2011 physical earthquake intensity measure obtained from shake-maps produced by USGS as an earthquakes damage proxy. However, this variable seem to have no explanatory power in these regressions, so we exclude it from the regressions we report.

[125] We use robust standard errors to control for the heteroscedasticity in the error terms.

[126] Optimized hot spot analysis (Getis-Ord Gi*) identifies areas where clusters of homeowners made the same decision. Clusters of red dots represent areas where homeowners choosing the Insurance option, while areas with blue dots show the cluster of homeowners choosing the crown option.

Figure 5-4 Optimized Hot Spot Analysis - RRZ Option choice



Optimized hot spot analysis (Getis-Ord Gi*) identifies areas where clusters of homeowners made the same decision. Clusters of red dots represent areas where homeowners choosing the Insurance option, while areas with blue dots show the cluster of homeowners choosing the crown option.

We estimate maximum likelihood spatial estimations for the set of linear probability regressions with mesh-block fixed-effects. The spatial specifications are the Spatial Autoregressive Model (SAR) and the Spatial Durbin Model (SDM). We compare the results with the standard linear probability least-squares estimation (OLS).

$$Y_i = \alpha_i + \beta X_i + \varepsilon_i \qquad (OLS)$$

$$Y_i = \alpha_i + \rho W Y_j + \beta X_i + \varepsilon_i \qquad (SAR)$$

$$Y_i = \alpha_i + \rho W Y_j + \beta X_i + \theta W X_j + \varepsilon_i \qquad (SDM)$$

The SAR model controls for the endogenous spatial interaction effects in the dependent variable: how neighbors' choices affect the decision of homeowner (i). The SDM model captures both endogenous and exogenous spatial interaction effects. This explains how the option choice and property's characteristics of surrounding neighbors influence the household decision regarding the option payment. When there are no spatial covariates (the spatial parameters ρ and θ are zero), the regression model is a simple linear probability model (OLS). W is a non-negative spatial weights matrix $(N \times N)$ describing the spatial structure of dependence across properties in the sample. In this paper, the row-standardized spatial weighted matrix (W) is constructed using the inverse distance weights. In other words, the elements w_{ij} of the matrix W indicate the inverse distance between properties i and j; $w_{ij} = 1/d_{ij}$ where d_{ij} is the distance between properties i and j. When d_{ij} is higher than one km, $w_{ij} = 0$. The estimation results and implications are explained in the next section.

5.5. Results

Table 5-3 presents the maximum likelihood estimation results of the binary choice probit models with log-transformed predictors. The probit results were already converted to the marginal effects on the predicted probability (instead of the estimated coefficients). The models explain the RRZ homeowner choice with independent variables. The simplest regressions (column 1-3) do not include meshblock fixed effects; whose aim is to control for differences in owners' characteristics that are present across meshblocks. These already show that property values are statistically significant in explaining the homeowner choice. The marginal effects of improvement value are negative but land value has positive marginal effect on the option choice.

In the Crown option ($Option_i = 0$), the RRZ households would receive the 2007 rating valuation of their house from the government. The properties with high improvement value tend to choose the Crown option. In contrast, for both Crown and Insurance options, every homeowner in the RRZ received the 2007 valuation of its land from the Crown. In the Insurance option, homeowner would deal with need to deal with both EQC and insurers to settle claim from the earthquake damage. We find that high land value would make the property owner more likely to take the Insurance option ($Option_i = 1$). This large/expensive land plot might contain valuable assets that were highly exposed to earthquake damage.[127]

The results of these property value variables remain consistently of the same sign and significance when other specifications are used. In column 4-5, we include damage indicators in the specifications. Both damage indicators are positively associated with our dependent variable ($Option_i$). The insurance claim payment was based on the assessed damage on the property, so it is not surprising that homeowners would be more likely to choose to deal with insurers for claim payment when the earthquake damage on their property

[127] The correlation between land value and the damage indicator is small but significantly positive. See Table 5-5

was higher.[128] On average, having the "total loss" status will increase the probability of choosing the Insurance option by over 30 percent, holding everything else constant. Its marginal effects are large, and we observe that the explanatory power of the model (the R-squared) increased significantly, especially when "Damage status" is included (column 5).

In addition, we note that the results of our main explanatory variables are consistent when household characteristics are included, shown in column 6. The Proportion of Full-time variable is negatively associated with the option choice. Areas with high full-time workers are likely to avoid dealing with insurers for their claim and choose to receive their 2007 house value from the government. The marginal effect of NZ Deprivation is very small relative to other variables' effects. In column 7, we add the meshblock fixed-effects to the previous estimations. In addition to the increase in the explanatory power of the model, the explanatory variables that were included in the previous specification retain their significance and magnitude.[129] For this specification, the probability that homeowner choose the Crown option increases by 18.6 percent points on average when the log value of improvement value increased by one standard deviation. Similarly, the probability choosing Insurance option increases by 25.4 percent points when the log value of land value increases by one standard deviation. The pseudo- R^2 for the last regression is 0.295; i.e., the variations in the independent variables explain 30 percent of the variation in the homeowner choice regarding RRZ options.[130]

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[128] We attempted to use the physical damage of Feb 2011 earthquake as damage indicator. However, its coefficient is not statistically significant in explaining the option choice.

[129] When we include MB fixed effect, 283 observations in the sample were dropped. This is because there is no within MB variation of the dependent variables.

[130] We also ran the same regression specifications set for each sub-sample (Christchurch Flat-land, Waimakariri and the Port Hills). The result can be found in the Appendix (tables 5-6, 5-7 and 5-8).

Table 5-3 Estimation results - Marginal effects of Probit models

VARIABLES	Dependent dummy variable – Option choice						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Improvement Value (log)	-0.096***		-0.174***	-0.176***	-0.222***	-0.228***	-0.186***
	(0.018)		(0.021)	(0.022)	(0.022)	(0.023)	(0.017)
Land Value (log)		0.110**	0.188***	0.187***	0.168***	0.156***	0.254***
		(0.053)	(0.041)	(0.042)	(0.041)	(0.041)	(0.028)
Damage Ratio				0.184***			
				(0.052)			
Damage Status					0.313***	0.309***	0.297***
					(0.011)	(0.010)	(0.009)
Proportion of House ownership						0.010	
						(0.063)	
Proportion of Full-time						-0.272**	
						(0.122)	
NZ-Deprivation 2006 Index						-0.015***	
						(0.004)	
Family Income (log)						0.042	
						(0.050)	
Proportion of Elderly						-0.079	
						(0.144)	
MB fixed eff.	No	No	No	No	No	No	Yes
Observations	7482	7482	7482	7482	7482	7375	7199
Psudo- R^2 (%)	1.23	1.49	4.74	5.12	20.76	21.8	29.54

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses.

Next, the results from the spatial linear probability specifications are provided in Table 5-4. In order to facilitate comparisons, we first report the linear probability model (OLS) in column 1. These contain the same explanatory variables as Table 5-3: improvement value, land value and damage status, with the meshblock fixed-effects. The main independent variables are statistically significant, with the same direction of effect and order of magnitude across the different spatial and non-spatial estimation methods. The linear probability model (OLS) gives us very similar result to the non-linear probit model in Table 5-3.

Table 5-4 Estimation results - Spatial linear probability model

VARIABLES	Dependent dummy variable – Option choice					
	OLS	SAR	SDM *(Total)*	SDM *(Chch. city)*	SDM *(Port Hills)*	SDM *(Wakamariri)*
Main						
Improvement Value (log)	-0.177***	-0.171***	-0.160***	-0.167***	-0.105***	-0.166***
	(0.011)	(0.010)	(0.011)	(0.014)	(0.028)	(0.020)
Land Value (log)	0.264***	0.254***	0.265***	0.300***	0.0311	0.270***
	(0.017)	(0.014)	(0.015)	(0.018)	(0.039)	(0.042)
Damage Status	0.372***	0.366***	0.368***	0.325***	0.573***	0.451***
	(0.012)	(0.009)	(0.009)	(0.012)	(0.035)	(0.018)
Spatial						
ρ		0.138***	0.132***	0.114***	-0.067	0.214***
		(0.016)	(0.017)	(0.020)	(0.076)	(0.039)
Wx						
Improvement Value (log)			-0.093***	-0.092***	-0.115**	-0.053
			(0.022)	(0.028)	(0.054)	(0.041)
Land Value (log)			-0.028	0.001	-0.046	-0.197**
			(0.027)	(0.031)	(0.065)	(0.078)
Damage Status			0.021	0.006	0.225**	0.0303
			(0.021)	(0.026)	(0.097)	(0.042)
MB fixed eff.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7482	7482	7482	5592	502	1388
Psudo- R^2 (%)	29.30	32.06	32.26	28.72	58.87	40.44

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses. Rho - ρ is the spatial autoregressive coefficient and Wx is the spillover effect coefficients. All models have Hausman *p*-value equal to zero.

We then include the endogenous (WY_i) and exogenous spatial lags (WX_i) in the models. We found that the parameter Rho (ρ) is positive and statistically significant. This means that the option choice of RRZ homeowner is influenced by her neighbors' choice. RRZ households in the same neighborhood may anticipate the options before making their decision.[131] This peer effect is shown clearly by clustering of properties choosing the same option in the optimized hot spot analysis (Figure 5-4). For example, in the SAR model, RRZ household would be 13.8 percent more likely to choose the Insurance option if their neighbors also took the same option. In the SDM model, the coefficients for spatial variables indicate the effect of neighboring property values and damage status on the estimated household observation. We find that only the spatial lag of improvement value variable is statistically significant. If the value of surrounding properties is high, the homeowner is more likely to go for the government offer.

We also replicate the same regression, after separating the sample into 3 sub-samples (Christchurch Flat-land, Wakamariri and the Port Hills). This allows us to compare the differences in property characteristics across these areas.[132] We find that they have similar results with the total sample, with exceptions in the Port Hills sample. The affected properties in the Port Hills were dispersed, in steep areas where the risks of rock fall and cliff collapse were high. Hence, unsurprisingly, the dependent spatial lag is small and statistically insignificant, indicating no clear relationship between the option choice of homeowner in the Port Hills and the option choice of her neighboring

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[131] There are several channels through which a peer can influence homeowner decision. For instance, there is an information advantage effect of following actions by a neighbour in financial decisions, since it reduces search costs, and perhaps also reduces perceived uncertainty of the decision process if the neighbour is trusted to make the right choice. Another example is when a homeowner's decision is influence by the choice of the majority of people in her network without analysing the options carefully. In this paper, we cannot distinguish between the channels (information channel, trusted peer, herd behavior and social pressure). However, our spatial models can show the existence of the peer influence.

[132] The result of direct and indirect effects of the spatial regression models are shown in Appendix Table 5.

households. Furthermore, in the Christchurch Flat land and Port Hills areas, the property value of neighborhoods also influences the homeowner's decision toward the Crown option. Households in the Port Hills are likely to go for the Insurance option when their neighbors had severe damages to the property.

5.6. Conclusion

We examined the NZ government property buyout in the Christchurch Residential Red Zone after the Canterbury earthquake sequence. We observe that homeowners' choices were, to a very substantial extent, driven by difficult to rationalize factors like the choices of their neighbors, or the value of their properties, rather than from a purely economic benefit assessment of the two choices they were given.

We examined the NZ government property buyout in the Christchurch Residential Red Zone after the Canterbury earthquake sequence. We observe that homeowners' choices were, to a very substantial extent, driven by difficult to rationalize factors like the choices of their neighbors, or the value of their properties, rather than from a purely profit maximizing assessment of the two choices they were given.

We find that RRZ homeowners choose the Insurance option when their land value is high. They tend to go for the Crown option when there is high improvement value or high earthquake damage to their property. In addition, areas with high full-time employment are more likely to choose the Crown option. These homeowners may view the opportunity cost of their time as higher, and therefore prefer the easier Crown option to avoid dealing with insurers for their claim payments. We also identify peer effect dynamics for household choice in the RRZ flat land. All of these provide us some insights regarding homeowner behavior during the relocation program, and may assist in the design of similar programs in the future.

The findings that emerged in this analysis lead to a host of subsequent questions for future research. For instance, which option was more cost-effective to owners and to the Crown? Are there any observable differences in the recovery path of households between the two option-groups? Are there any noticeable differences in their subjective satisfaction from the outcomes between the two groups? Are there any connections between the amount of funds they received and the timing for the property payout with different aspects of recovery process? What were the barriers or inequities (if any) in the acquisition process? Do neighborhood-peer effects exist in other similar programs? What was the impact of the managed retreat program on vulnerable households? Could the design of the program have been done differently to achieve improved outcomes?

Appendix Tables

Table 5-5 Correlation table of explanatory variables

	Improvement Value	Land Value	Damage Status
Improvement Value	1		
Land Value	0.3936	1	
Damage Status	0.1948	0.1302	1
Damage Ratio	0.0563	0.0381	0.1766

Data are from LINZ and EQC at property level. All correlation coefficients are significant at 1% confidence level.

Table 5-6 Estimation results - Marginal effects of Probit models (Christchurch – Flat land sample)

VARIABLES	Dependent dummy variable – Option choice						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Improvement Value (log)	-0.100***		-0.171***	-0.172***	-0.228***	-0.218***	-0.204***
	(0.024)		(0.023)	(0.023)	(0.022)	(0.020)	(0.020)
Land Value (log)		0.204***	0.246***	0.247***	0.229***	0.238***	0.315***
		(0.047)	(0.045)	(0.046)	(0.035)	(0.026)	(0.0243)
Damage Ratio				0.109**			
				(0.055)			
Damage Status					0.295***	0.289***	0.267***
					(0.013)	(0.012)	(0.010)
Proportion of House ownership						0.117	
						(0.103)	
Proportion of Full-time						-0.242	
						(0.148)	
NZ-Deprivation 2006 Index						-0.012***	
						(0.004)	
Family Income (log)						-0.047	
						(0.052)	
Proportion of Elderly						-0.007	
						(0.165)	
MB fixed eff.	No	No	No	No	No	No	Yes
Observations	5,592	5,592	5,592	5,592	5,592	5,535	5,397
Psudo- R^2 (%)	0.01	4.02	6.49	6.61	19.14	20.42	26.96

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses.

Table 5-7 Estimation results - Marginal effects of Probit models (Wamakariri – Flat land sample)

VARIABLES	Dependent dummy variable – Option choice						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Improvement	-0.0510*		-0.105***	-0.104***	-0.158***	-0.159***	-0.155***
Value (log)	(0.029)		(0.032)	(0.031)	(0.021)	(0.022)	(0.028)
Land Value (log)		0.240***	0.296***	0.297***	0.244***	0.206***	0.201***
		(0.057)	(0.057)	(0.052)	(0.032)	(0.035)	(0.038)
Damage Ratio				0.327***			
				(0.090)			
Damage Status					0.330***	0.326***	0.321***
					(0.013)	(0.013)	(0.009)
Proportion of House ownership						0.081	
						(0.143)	
Proportion of Full-time						0.0144	
						(0.265)	
NZ - Deprivation 2006 Index						-0.002	
						(0.006)	
Family Income (log)						-0.026	
						(0.058)	
Proportion of Elderly						-0.300	
						(0.270)	
MB fixed eff.	No	No	No	No	No	No	Yes
Observations	1,388	1,388	1,388	1,388	1,388	1,360	1,378
Psudo- R^2 (%)	0.01	3.02	4.63	6.56	38.25	39.45	43.66

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses.

Table 5-8 Estimation results - Marginal effects of Probit models (Port Hills sample)

VARIABLES	Dependent dummy variable – Option choice						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Improvement Value (log)	-0.106*		-0.087**	-0.090**	-0.117***	-0.110***	-0.114***
	(0.057)		(0.038)	(0.036)	(0.024)	(0.023)	(0.030)
Land Value (log)		-0.086	-0.023	-0.054	-0.050	-0.061*	0.004
		(0.067)	(0.065)	(0.060)	(0.035)	(0.034)	(0.072)
Damage Ratio				0.827***			
				(0.183)			
Damage Status					0.496***	0.451***	0.402***
					(0.044)	(0.033)	(0.022)
Proportion of House ownership						0.152	
						(0.500)	
Proportion of Full-time						0.163	
						(0.223)	
NZ - Deprivation 2006 Index						0.0103	
						(0.013)	
Family Income (log)						0.341***	
						(0.092)	
Proportion of Elderly						0.476	
						(0.378)	
MB fixed eff.	No	No	No	No	No	No	Yes
Observations	502	502	502	502	502	480	419
Psudo- R^2 (%)	4.12	3.02	4.22	9.56	39.54	41.73	45.06

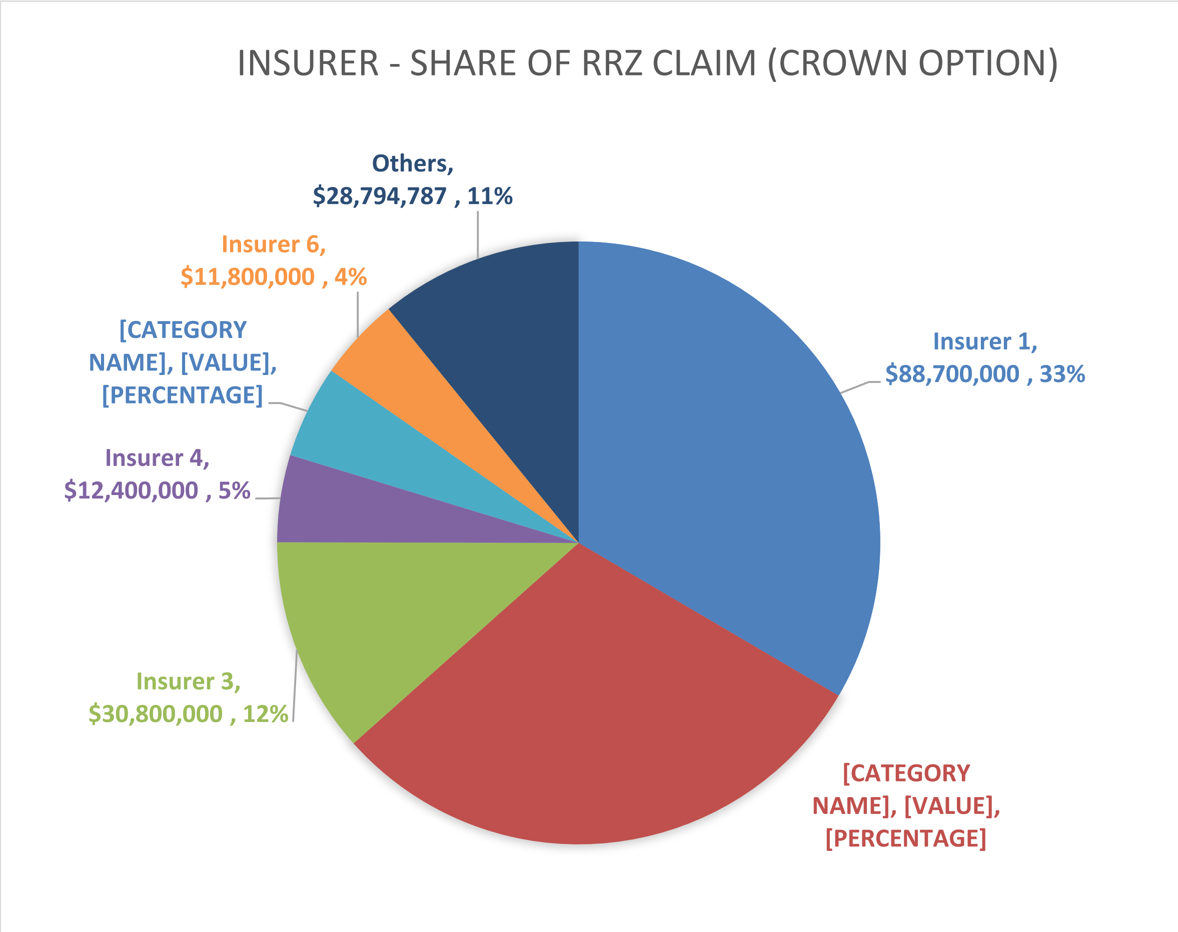
***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses.

Table 5-9 Model comparison of the estimated Direct and Indirect effects on Option choice

	SAR	SDM *(Total)*	SDM *(Chch. city)*	SDM *(Port Hills)*	SDM *(Wakamariri)*
Direct effect					
Improvement Value (log)	-0.171***	-0.162***	-0.169***	-0.104***	-0.170***
	(0.011)	(0.011)	(0.014)	(0.028)	(0.020)
Land Value (log)	0.254***	0.265***	0.301***	0.032	0.265***
	(0.014)	(0.015)	(0.018)	(0.039)	(0.041)
Damage Status	0.367***	0.369***	0.326***	0.572***	0.456***
	(0.009)	(0.009)	(0.012)	(0.035)	(0.018)
Indirect effect					
Improvement Value (log)	-0.026***	-0.129***	-0.123***	-0.102**	-0.110**
	(0.004)	(0.024)	(0.030)	(0.050)	(0.049)
Land Value (log)	0.039***	0.006	0.039	-0.045	-0.172*
	(0.005)	(0.029)	(0.033)	(0.062)	(0.091)
Damage Status	0.057***	0.078***	0.048*	0.176**	0.156***
	(0.007)	(0.023)	(0.027)	(0.079)	(0.045)

Appendix Figures

Figure 5-5 Share of RRZ claims in the Crown Option sample



*Notes: Total NZ$265 million of insurance for Crown option properties. The share of RRZ claim can be representative for the market share of individual insurers. The insurers' names are anonymized for confidentiality.

Chapter 6

Who Cares? Future sea-level-rise and house prices

Abstract

Globally, the single-most observable, predictable, and certain impact of climate change is sea level rise. Using a case study from the Kapiti Coast District in New Zealand, we pose a simple question: Do people factor in the warnings provided by scientists and governments about the risk of sea-level rise when making their investment decisions? We examine the single most important financial decision that most people make – purchasing a home, to see whether prices of coastal property change when more/less information becomes available about property-specific consequences of future sea level rise. The Kapiti Coast District Council published detailed projected erosion risk maps for the district's coastline in 2012 and was forced to remove them by the courts in 2014. About 1,800 properties were affected.

We estimate the impact of this information on home prices using data from all real estate transactions in the district with a difference-in-differences framework embedded in a hedonic pricing model. We find that the posting of this information had a very small and statistically insignificant impact on house prices, suggesting people do not care much about the long-term risks of sea-level rise as they do not incorporate these risks in their investment decisions.

6.1. Introduction

Globally, the single-most observable, predictable, and certain impact of climate change is sea level rise. "Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m….The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (high confidence)." (IPCC, 2014). The current scientific consensus about future sea-level rise was also summarized by the IPCC (Intergovernmental Panel on Climate Change):

"Global mean sea level rise will continue during the 21st century, very likely at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6 [best likely case scenario], and of 0.45 to 0.82 m for RCP8.5 [worst likely case scenario]….Sea level rise will not be uniform across regions.…About 70% of the coastlines worldwide are projected to experience a sea level change within ±20% of the global mean."(IPCC, 2014).

Using a case study, we pose a simple question: Do people factor in the warnings provided by scientists and governments about the risk of sea-level rise when making their investment decisions? We examine the single most important financial decision that most people make – purchasing a home, to see whether prices of coastal properties change when more/less information becomes available about the property-specific consequences of future sea level rise (SLR).

In order to identify an empirical answer to this question, we use a unique case study from one local council in New Zealand – the Kapiti Coast District Council. In this case, the District Council produced detailed projected erosion risk maps (SLR-related) for the whole district's coastline and published it in 2012. This projected risk assessment was conducted for 50- and 100-year horizons and with and without coastal protection and management changes being implemented. Based on the findings of the assessment, the Council notified some 1,800 affected households that were placed in zones deemed to be at risk of erosion because of future sea-level rise, and this hazard risk information was placed on Land Information Memorandums (LIM) held by the council. These LIMs are made available to every property buyer, and it is standard practice that LIMs are examined by the buyer and their legal representatives during the purchase process.

Following the placement of this future risk information on the LIMs, substantial negative reactions by current owners of these properties ensued. Coast Ratepayers United, a local group of homeowners, was formed and fought to remove the hazard warnings from the LIMs. The group challenged through the courts the accuracy of the Council's analysis and the limited scope of public consultation. Reaching the High Court, the presiding judge ruled that while the council was within its legal rights to assess and note hazards, the lines had the 'potential to seriously affect the value and marketability of coastal properties in the district' putting 'millions of dollars at stake' and hence the process needed to be more 'clear, fair and balanced' (Haxton, 2014). Following this decision, the council decided to remove the hazard lines from the LIMs and these maps were removed from online access.

Given the known timing of the posting of this information, and its subsequent removal, we can estimate the impact of this information on home prices. We use a difference-in-differences framework to measure if public disclosure coupled with notices placed on coastal properties were capitalized into the prices of affected residential properties, and whether this price effect ceased after the information was removed in 2014.

These questions, of course, are not relevant only for the residents of the Kapiti Coast (a coastal strip just to the North and West of the capital, Wellington). In 2006, 65% of the total population of New Zealand lived within 5 km of the country's coasts (Statistics NZ, 2016). The main concentrations of population in the low-lying coastal areas are in the densely populated urban settlements, and an estimated NZ$ 52 billion worth of building assets are exposed to coastal risk (NIWA, 2015). As changes in values of residential properties on the coast may also affect the value of nearby properties and entire neighborhoods, these questions have an impact on the home value of many New Zealanders, and of course, in many other countries.

6.2. Literature on Coastal Risks and Coastal Properties

6.2.1 Quantifying the damage from SLR

Not surprisingly, SLR has drawn the attention of researchers globally. With advances in methodologies and geo-spatial data, strategies for country-level and global scale estimation of the impact of SLR on existing assets have emerged (Tol, 2007; Sugiyama et al., 2008; Tol et al., 2008). Although useful for framing a national approach to climate policy, such studies lack generalizability for estimating the costs of SLR at a local and the micro scales due to variations in geo-morphology as well as socioeconomics and politics.

The emergence of microeconomic research on the impacts of SLR has been rather slow, with studies primarily originating from North America. For example, Yohe et al. (1995) estimated the potential loss of land and built structures with aggregate property data for South Carolina. Following the method developed by Yohe et al. (1995), but using disaggregated property transaction data, Parsons and Powell (2001) estimated the cost of beach retreat in Delaware to the year 2050 to be around $291m (in USD valued in 2000). Michael (2007) considered the impact of increased storm surge flooding in Chesapeake Bay communities and found that damage from storm floods may be 28 times greater under a 2-foot SLR scenario. On the North Carolina coast the magnitude of future property value losses because of SLR varies with the location and level of development (Bin et al., 2011); while in Florida coastal inundation costs can reach $7b (Fu et al., 2016)).

McAlpine et al. (2018) look at flood risk in Miami and the way it is changing because of SLR. They find a small but statistically significant impact on property prices. However, in the Miami case, there is little chance that these properties will be abandoned given their very high values and, at least according to current law, they will be able to continuously remain insured through the U.S. National Flood Insurance Program (NFIP).

Hidano et al. (2015) use regression discontinuity design and seismic risk maps to similarly identify the price impact of SLR risk. They find a very small but statistically significant difference. Walsh et al. (2019) focus on the property value of protection from SLR in Chesapeake Bay in the United States. They find a significant and consistent loss in value associated with SLR risk, using a similar method to Hidano et al. (2015). None of these studies however capture the provision of readily accessible climate change risk information, which is the focus of the current paper.

An attempt to measure the 'average' or aggregate effect might be heterogeneous. Different agents could have, for example, different views about temporal discounting or may have a different awareness of the risk. In a recent study, Bernstein et al. (2018) estimated a 7% discount in home prices exposed to SLR with further evidence of deeper discounts among more 'sophisticated' buyers and sellers. Similarly, Baldauf et al. (2018) observed that differences in beliefs about SLR (climate change believers vs deniers) are reflected in house prices with properties in 'believer' neighborhoods selling at a discount compared to 'denier' neighborhoods.

6.2.2 Quantifying the effects of flooding events on property prices

A separate stream of research has investigated the effects of catastrophic natural hazards on house prices, showing robust empirical evidence that homeowners tend to adjust their perceptions of future risk (and consequently prices) in response to the occurrence of a disaster. In most studies, however, the effect of these catastrophic events on prices is fairly short-lived, with prices returning to their previous pre-disaster level after 2-3 years at most (Atreya et al., 2013). Sometimes, the effect of catastrophic events is even measured only in months (Deng et al., 2015). Researchers have examined both the impact on prices in the same location in which the catastrophic event has occurred, but in undamaged properties (Deng et al., 2015); and in locations that are perceived to be similar in their risk profile but that were not directly affected by the catastrophe (Timar et al., 2018b, 2018a).

In an efficient market with homeowners well-informed of risks, fully insured properties should trade at a discount equal to the capitalized value of insurance premiums (Bin and Landry 2013). A priori, if the occurrence of the disaster does not provide any new information (i.e., it was just an 'unlucky' draw from a known independent distribution) it should not have any impact on prices. Conversely, if owners underestimated the risks and now face increasing insurance costs (i.e., insurers similarly underestimated the risk), reductions in property value can be substantial.

Thus, the empirical evidence from this literature suggests that such flood risks tend to lead to discounted property prices (Rajapaksa et al., 2016). Public disclosure of risks, even in the absence of an actual event, has been shown to discount prices. For example, a study of flood hazards in Auckland, New Zealand, found that properties in the flood plain were discounted by 2.3% when their risk profile was made available to the public (Samarasinghe & Sharp, 2010).

Our study, in contrast, is concerned with the effect of new information about future projected climate-change risk on the dynamics of coastal house prices, rather than of past events or existing risks. It is, to our knowledge, the only study to focus on this question.

6.2.3 *Challenges in identifying the importance of new information about SLR*

Indisputably, coastal hazards and coastal amenities are spatially correlated and highly dependent. There exists a trade-off between hazards and amenities offered by living close to the coast. Some studies of coastal areas point to the presence of a price premium rather than the expected discount, as these estimations fail to account for appreciable coastal amenities such as sea views and accessibility to the coast (Beltrán et al., 2018). A few studies account for such competing effects and therefore provide improved more genuine estimate of the inundation risk discount suffered by residential properties due to SLR. Bin et al. (2008) suggest that incorporating GIS-based view measures (view-scope and distance to coast) helps disentangle coastal risk from coastal amenities. In the presence of the view amenities, coastal risk devalued properties in North Carolina beach communities by approximately 11%. Likewise, studying the state of Queensland in Australia, Rambaldi et al. (2014) isolated inundation risk discount in house prices taking into account views and proximity to the ocean and waterways.

Previous findings also suggest that any discount associated with proximity to the ocean and SLR is not uniform and varies with location and owners' beliefs about climate change, demonstrating the importance of micro-level research. Factors such as sea views and recreational access potentially mask or override property value reductions. Furthermore, rising property markets and expectations of future capital gains can potentially desensitize prospective buyers of SLR risks (DEFRA, 2009).

Yet, there is no published empirical evidence to determine if official information about future coastal hazard risk is reflected in house prices. The question here is not what is the price discount associated with being within the erosion-risk line, but rather what is the price impact of that information, once and when it is provided to prospective homebuyers and sellers. This is an important policy question. Attempts by local authorities to notify residents of hazards remain controversial and often draw backlash and anxiety from affected households. Owners typically cite anecdotal evidence on the negative impacts on property value following public disclosure of risks and are therefore often vehemently opposed to public disclosure.

While public opposition to the supply of risk information roars in the background, assessments by two regional councils in New Zealand argue that coastal hazards do not affect property values. Furthermore, these local government authorities insist that broader property market and economic factors far outweigh any stigma that may be perceived by any public warning about hazard risk ((Environment Waikato, 2006; Environmental Management Group, 2008).[133] With these opposing views in mind, our aim is to assess the crux of the debate: does public disclosure of hazard risks impact house prices?

[133] Since 2000 and leading up to the GFC, New Zealand property market has experienced a surge in demand for housing, when house prices increased in real terms by 77% (Kendall, 2016). The most recent rise in house prices began in 2012, surpassing the peak of the previous property cycle.

6.3. Study methods

We use a difference-in-difference (DID) regression method estimated within a hedonic model of property sale prices. This DID design allows us to identify the effect of public disclosure of coastal hazard risk on property prices. Properties that are located in the reported coastal hazard zones are the treatment group and properties in the Kapiti Coast District but outside the reported coastal hazard zones are the control group. Because both groups are located in the same area, their property value is influenced by similar contemporaneous factors. In addition, we are able to control for coastal amenities, specifically their distance from the coast and the existence and quality of their 'sea-view'. Two other factors assist us in the identification. First, the hazard lines were known to the public for a well-defined period of time (September 2012 through October 2014). Second, the lines were not drawn at equal distance from the ocean along the Kapiti Coast, further allowing us to identify the price difference associated with the hazard lines and differentiate it from amenities associated with proximity to the coast.

This approach allows us to extract the effect of reported hazard risk on property price from other variables. The DID model is designed as follow:

$$GrossPrice_i = \beta_0 + \beta_1 Post_i + \beta_2 Affect_i + \beta_3 Post_i Affect_i + \beta_k X_i^k + \sum_{c=1}^{C} \beta_c D_i^c + \varepsilon_i \quad [1]$$

In the specification, the variable $Affect_i$ takes value of 1 if the property (i) is located inside the coastal hazard lines and 0 otherwise. The control group ($Affect_i = 0$) are properties outside the hazard areas. $Post_i$ is a binary variable equal to 1 if the transaction sale occurs after the public disclosure date of the coastal erosion prediction maps (from September 2012 onward). The interaction term between $Affect_i$ and $Post_i$ is the difference-in-difference treatment effect showing how the public disclosure of hazard risk affected the local property price. The natural log of sale price is used as the dependent variable $GrossPrice_i$.

The hedonic function is estimated in the log-linear form with two types of explanatory variables. The specification includes house-specific characteristics, k, and location as control variables (X_i^k).[134] They are: building floor area, site area, internal and external condition, type of external cladding, extent of sea view, land contour, and elevation. All continuous variables are converted to natural logarithm form. In addition, census-area unit, deprivation index, quarter sold, and vintage (decade of construction) fixed effects (D_i^c) are included to capture the time-invariant characteristics that may affect all the properties across different groups.

6.4. Study area and Data

6.4.1 Kapiti Coast study area

The Kapiti Coast is a coastal area in the south-west corner of the North Island of New Zealand (see Figure 6-1). In 2012, Kapiti Coast District Council (KCDC) was preparing for a new District Plan. The main focus for KCDC and local community was how to respond to coastal erosion risks in the coming decades (KCDC 2012). The management of the risk was perceived as more urgent with already-occurring sea level rise and other future potential effects of climate change. Policy 24 in the NZ Coastal Policy Statement of 2010 states: "*[the policy statement] requires councils to identify areas in the coastal environment that are potentially affected by coastal hazards … over at least 100 years … including the effects of climate change.*"

[134] Because the Kapiti Coast area has not experienced any large/moderate disaster event in recent times, we do not control for any physical damage to properties associated with such events. There are very few insurance claims related to hydro-meteorological hazards in the last 30 years in the Kapiti Coast district (Fleming et al., 2018).

As a result, a detailed coastal hazard assessment was carried out by Dr Roger Shand of Coastal Systems Limited (CLS), an experienced coastal hazard expert, and completed by August 2012. This report followed best-practice guidance and was peer-reviewed by other experienced coastal engineers and scientists. It defined a series of potential 'future shorelines' based on managed and unmanaged scenarios with 50- and 100-year planning time frames (Shand, 2012). The projected shorelines take into account both current and future risks.[135]

The coastal erosion projections were conducted based on detailed analysis of current and historic data (KCDC, 2012). The collected data included past coastal hazard studies in the region, historic aerial photographs (1940s to present), cadastral surveys (1890s to present) and projections of future climate change and sea-level rise from the Ministry for the Environment guideline (2008).

The hazard risk information was then put on affected property's Land Information Memorandums (LIMs) and notification letters were sent to affected property owners on 25th August 2012 as required by the Local Government Official Information and Meeting Act.[136] The coastal LIMs contained neighborhood maps of shoreline projections to inform people about the hazard risk in their neighborhood. According to the KCDC's statistics, coastal erosion would endanger up to 1,000 properties within 50 years, and 1,800 properties would be at risk within 100 years. The current capital value of affected properties was estimated to be NZ$ 1.6 billion (KCDC, 2012).

The public disclosure of hazard information led to an immediate public and media outcry. A high-profile interest group - Coast Ratepayer United - was

[135] Current risks are storm erosion and catch-up erosion (after the loss of protection work for unmanaged scenarios). Future risks are the effect of projected sea-level rise and continuation of existing erosion trends.

[136] KCDC (2013) provides a detailed timeline of consultation and communication activities before and after the release of coastal hazard line information in August 2012.

formed to prevent the dissemination of this report of coastal hazard lines and challenge the assessments with public pressure applied onto elected district council members. In 2013, coastal residents requested a High Court Judicial Review and sought to exclude the coastal hazard information from LIMs report. In December 2013, Judge Joe Williams ruled that under Section 44A(2)(a) of the Local Government Official Information and Meetings Act 1987: "*KCDC had no choice but to note coastal hazard information, contained in the Shand Report, on LIMs.*"

The judgment found the KCDC had no discretion in this regard and was obligated to make the information available in a clear manner (KCDC, 2013). However, the judge also ruled that: "*The lines were starkly simplistic as a summary of the complex Shand information and have the potential to seriously affect the value and marketability of coast properties*."

Due to the pressure from the Coast Ratepayer United group, KCDC decided to remove all coastal erosion line maps and related explanatory text from LIMs in October 2014 (KCDC, 2014). In November 2017, the council released a new Proposed District Plan with no erosion hazard information or provisions in it.

Figure 6-1 illustrates the four coastal erosion lines with an example from a settlement in Kapiti Coast called Waikanae. These hazard lines represent different scenarios for 50-year and 100-year projection periods. These scenarios indicate what is expected to happen due to coastal inundation caused by storm events and shoreline retreat caused by coastal erosion. The 50- and 100- year natural line maps presume that existing seawalls are not repaired and eventually erode themselves.[137] While the 50- and 100- year

[137] According to the NZ Coastal Policy Statement and Wellington Regional Policy Statement, the KCDC does not support hazard protection structures such as seawalls because they are unlikely to provide a long-term solution to coastal erosion in Kapiti Coast district.

managed line maps assume the management/maintenance of current public seawalls/inlets and other protection works.

6.4.2 *Property transactions and other data*

This study analyzes sales transactions of freestanding houses (excluding flats and apartments) sourced from CoreLogic for Kapiti Coast District Council from Q1 2009 through Q1 2018. Transactions were excluded from analysis if they were suspected to include data entry errors. Specifically, houses were removed if the floor area was less than 30 square meters or over 500 square meters, if lot size was over 2,000 square meters, or had any missing data. Also transactions were deleted if flagged as outliers (standardized residuals beyond three standard deviations), had leasehold rather than freehold interests or were explicitly coded as not reflecting an arm's length transaction (e.g. non-market sales price, related party sales, etc).

As the home sales transaction dataset from CoreLogic does not include certificate of title unique identifiers nor does it provide full address information (only street name and an indication of whether the property's street number was odd or even), a series of steps were required to associate each sales transaction with its respective land title, which is subject to hazard warnings stated on the property's LIM.

Land title information is sourced from Landonline, the system used to manage New Zealand's land information. It is comprised of numerous spatial and attribute databases that comprise the country's cadastral (land title and property ownership) and topographic information. Data held by Landonline can be freely accessed online at https://data.linz.govt.nz/.[138]

[138] For the purposes of linking sales transactions to their respective land titles, several relevant Landonline databases must be acquired and manipulated including 'street addresses', 'property titles', 'title memorial text' and 'title instruments'.

The first objective is to identify title transfers in the Kapiti Coast District that have occurred within the study timeframe (2009 through 2018). Consideration must be given to the fact that there is a time lag between a property's sales date (when a willing buyer and seller agree to specific terms and conditions and execute a conditional sale and purchase agreement) and its settlement date when the title is transferred, within Landonline, from the seller to the buyer. The elapsed time between sale date and settlement (transfer) date averages 11 weeks but ranges from zero (same day) to over a year. Therefore, title transfers that have occurred between Q1 2009 through Q4 2018 are analyzed to take into account the duration between sale and transfer.

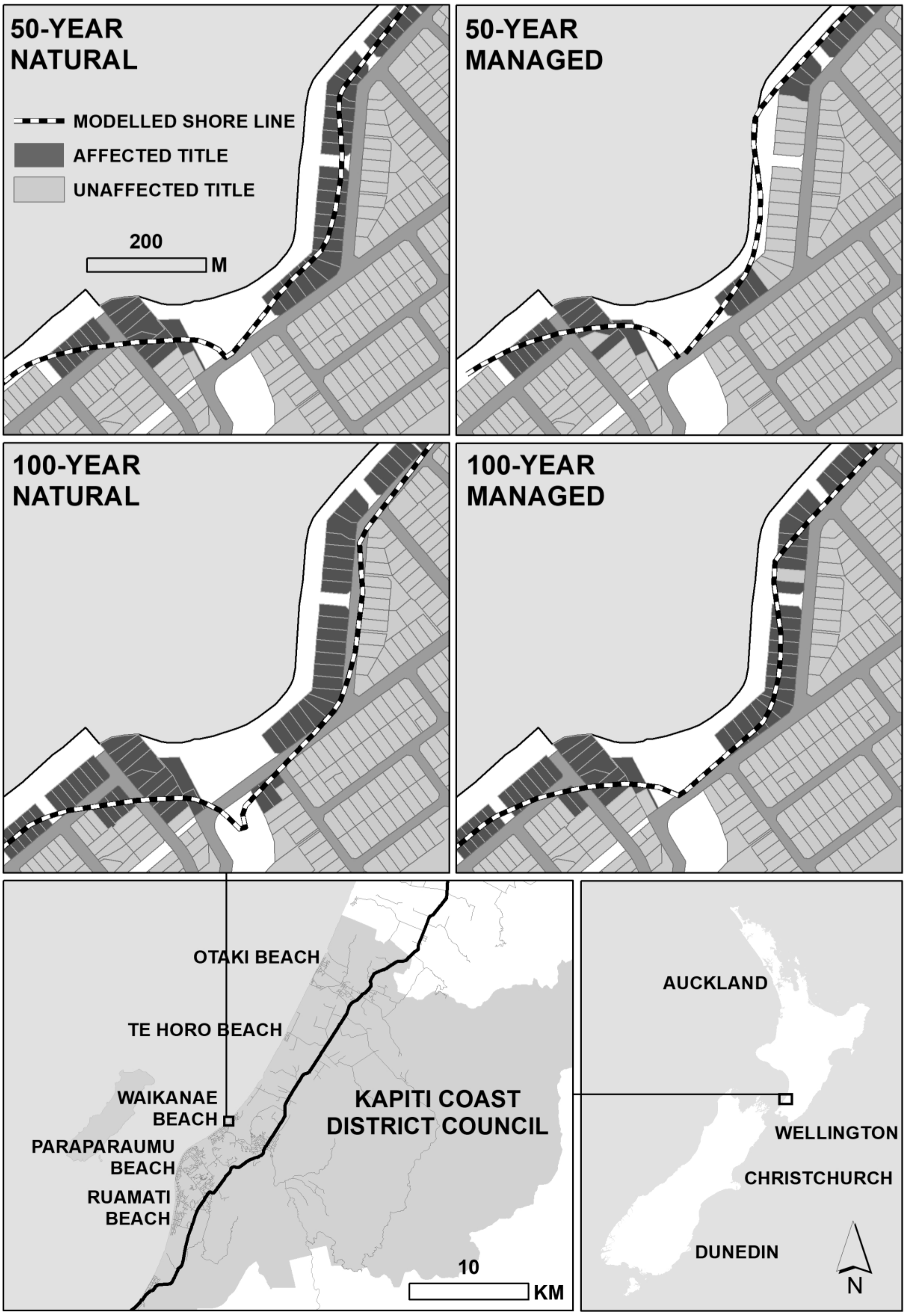
With transferred titles identified the next step is to remove from the dataset of non-market, related party transfers (e.g. homeowners transferring title to a family trust). Title owner names are acquired from Landonline's 'title memorial text' dataset and used to identify related parties through comparisons of buyer and seller names. When a match is found the transfer is assumed to involve related parties and is removed from consideration. The remaining non-related party, or market, title transfers are then associated with their respective land titles using Landonline's 'title instrument title' dataset.

Land titles that experienced at least one legitimate, market transfer is downloaded from the LINZ Data Service as a polygon GIS shapefile theme. Through use of geographic information system (GIS) software these land title polygons are spatially joined to Landonline's street addresses (point theme). This geoprocessing operation appends the LINZ database of title transfers with the full street address of each land title that was transferred (sold) within the study timeframe.

With full addresses linked to land titles, sales transaction records are then married to their respective land title transfer record using the available partial street address information, land parcel size (available in both sales transactions and land title databases) and sales/settlement (transfer) dates. This enables us to ascertain the exact land title associated with each of the 8,436 freestanding home sales transactions that occurred within the Kapiti Coast District during the study timeframe.

The district's land titles polygons were overlaid with drawing exchange format (DXF) line themes representing each of the four modelled 'future shorelines'. These DXF files were provided by Dr Roger Shand for use in this study. Figure 6-1 provides an illustration of how these line themes are used to code land titles as being affected or not.

Figure 6-1 Study area location and coastal erosion scenarios



(There are 4 classifications, corresponding with the 4 coastal hazard risk lines, as presented in Figure 6-1, with an example from Waikanae. The number of treated observations in each specification are 577 (50 yr nat), 521 (50 yr managed), 347 (100 yr managed) and 130 (100 yr natural) out of 8,436 sale transactions between 2009-2017.)

The period in which the hazard maps appeared on LIMs (September 2012 through October 2014) does not seem out of the ordinary for the affected properties in terms of the number of sales when plotted against the control group and for the whole period (2009-2017) as shown in figure 6-3. As for all other properties, there was a slowdown in sales that started in 2006 and hit a trough in 2008; this was the local manifestation of the Global Financial Crisis. Volume of residential sales did not recover until several years later, in 2011, albeit never reaching the peaks of the previous property cycle. Similar observations are had when we examine the average (mean) sale price (Figure 6-4) for all the sub-samples – properties in the 50-year-managed, 50-year-unmanaged, 100-year-managed, 100-year-unmanaged, and the control group (properties further away or higher up from the coast).

Two additional observations are worth making. First, it was reported in the media that following the successful court challenge and removal of hazard warnings from LIMs, many owners of affected properties subsequently sold their houses (Cann, 2017). This however, is not the case. The volume of transactions of affected properties in the months following the removal of hazard lines from LIMs, in October 2014, is well within the normal range; any uptick merely correlates with a more general uptick in property sales across the district. Second, the observation that the market for affected properties correlates closely with the wider property market suggests that, looking at the number of property transactions, there is most likely no selection problem. The decision whether to sell or not appears unrelated to the placement of erosion risks on LIMs in September 2012 or to their removal in October 2014.

Table 6-1 reports the summary statistics of key variables considered in our study. The average property sale price was NZ$384,000. Properties in control groups (A and C) were sold at 40 – 45% lower price, compared to properties in treated groups (B and D)[139]. This trend arises from the premium for the coastal amenities, such as beach access and uninterrupted sea views. The gross sale price increased more over time in the treated groups. The building floor area and site area are very similar across the control and treatment groups. Mean floor areas range from 154 to 157 m^2 while mean site areas fall into a tight cluster between 765 to 792 m^2.

Regarding property interior condition there are 17% properties coded as good quality and 5.8% reported as poor interior quality. Houses in the treated groups are more likely to have poor interiors (13%). The exterior quality for most properties (63%) of both groups is coded as being in good condition. In addition, houses in the treated groups tend to be on steep land and have superior sea views than houses in the control groups.

139 In the descriptive statistics table, the treated group includes all the residential properties that fall within the four coastal hazard lines.

Table 6-1 Summary statistics of key variables at property level

VARIABLE	A. Pre_Control (n=2,245)	B. Pre_Treated (n=178)	C. Post_Control (n=5,614)	D. Post_Treated (n=399)	Overall (n=8,436)
Gross sale price (NZ$)					
Mean (SD)	363,000 (119,000)	515,000 (236,000)	377,000 (136,000)	541,000 (257,000)	384,000 (148,000)
[Min, Max]	[47,000, 1,200,000]	[170,000, 1,300,000]	[20,000, 1,220,000]	[125,000, 1,620,000]	[20,000, 1,620,000]
Decade of construction					
1900	8 (0.4%)	1 (0.6%)	12 (0.2%)	1 (0.3%)	22 (0.3%)
1910	7 (0.3%)	2 (1.1%)	22 (0.4%)	5 (1.3%)	36 (0.4%)
1920	37 (1.6%)	6 (3.4%)	75 (1.3%)	17 (4.3%)	135 (1.6%)
1930	31 (1.4%)	8 (4.5%)	72 (1.3%)	30 (7.5%)	141 (1.7%)
1940	69 (3.1%)	9 (5.1%)	156 (2.8%)	25 (6.3%)	259 (3.1%)
1950	231 (10.3%)	24 (13.5%)	613 (10.9%)	44 (11.0%)	912 (10.8%)
1960	274 (12.2%)	20 (11.2%)	646 (11.5%)	62 (15.5%)	1002 (11.9%)
1970	357 (15.9%)	29 (16.3%)	835 (14.9%)	62 (15.5%)	1283 (15.2%)
1980	358 (15.9%)	37 (20.8%)	1063 (18.9%)	64 (16.0%)	1522 (18.0%)
1990	326 (14.5%)	17 (9.6%)	816 (14.5%)	49 (12.3%)	1208 (14.3%)
2000	414 (18.4%)	8 (4.5%)	838 (14.9%)	12 (3.0%)	1272 (15.1%)
2010	56 (2.5%)	2 (1.1%)	283 (5.0%)	3 (0.8%)	344 (4.1%)
Floor area (m2)					

Mean (SD)	157 (63.0)	155 (68.9)	154 (61.2)	157 (70.2)	155 (62.3)
[Min, Max]	[30, 450]	[40, 380]	[30, 470]	[30, 400]	[30, 470]
Site area (m2)					
Mean (SD)	792 (255)	780 (242)	769 (261)	765 (255)	775 (259)
[Min, Max]	[261, 1,980]	[358, 1,820]	[214, 1,990]	[313, 1,850]	[214, 1,990]
Good interior quality					
Yes	402 (17.9%)	35 (19.7%)	921 (16.4%)	74 (18.5%)	1,432 (17.0%)
Poor interior quality					
Yes	118 (5.3%)	24 (13.5%)	298 (5.3%)	52 (13.0%)	492 (5.8%)
Good exterior quality					
Yes	1,406 (62.6%)	101 (56.7%)	3,635 (64.7%)	227 (56.9%)	5,369 (63.6%)
Poor exterior quality					
Yes	41 (1.8%)	6 (3.4%)	93 (1.7%)	10 (2.5%)	150 (1.8%)
Steep land					
Yes	90 (4.0%)	21 (11.8%)	216 (3.8%)	40 (10.0%)	367 (4.4%)
Crosslease 2 owners					
Yes	68 (3.0%)	10 (5.6%)	335 (6.0%)	33 (8.3%)	446 (5.3%)
Crosslease 3+ owners					
Yes	12 (0.5%)	3 (1.7%)	79 (1.4%)	8 (2.0%)	102 (1.2%)
Slight sea view					

Yes	88 (3.9%)	23 (12.9%)	210 (3.7%)	56 (14.0%)	377 (4.5%)
Moderate sea view					
Yes	85 (3.8%)	45 (25.3%)	168 (3.0%)	108 (27.1%)	406 (4.8%)
Wide sea view					
Yes	50 (2.2%)	48 (27.0%)	87 (1.5%)	89 (22.3%)	274 (3.2%)

6.5. Results

Table 6-2 presents the results of the DID estimation for the four coastal hazard scenarios. The models achieve a reasonable fit, with adjusted R^2 ranging between .771 and .774. All of the house-specific and location control variables are estimated with the expected signs and are statistically significant. Coastal amenities, such as sea views and proximity to the coast, positively influence the price. While a property that enjoys a wider sea view will receive a higher sale price, positioning further away from the coast does not command as much benefit from the same appreciable water view.

As noted before, we consider the period in which 'treatment' took place as the one after the announcement of Coastal Erosion Hazard Risk report and lodgment of hazard warnings on affected properties' LIMs in September 2012. As such, the main coefficient of interest is the difference-in-difference coefficient – *post*affected* – presented in the Table 6-2. We find that public disclosure and the presence of coastal erosion risk on a property's LIM report has no statistically significant effect on house prices, albeit having a negative sign. This is contrary to our expectation and popular opinion that public knowledge of future risks of sea level rise would cause the affected properties to be discounted.

Across the four estimations, the largest (yet not significant) effect is observed among properties that fall within the 50-year managed scenario and is estimated to be a negative 5.9% (column 4, table 6-2)[140]. As these properties would be 'the first to go' having the highest risk of exposure to coastal inundation and erosion, this is to be expected. It appears that buyers of

[140] In this regression set, we apply robust standard error to control for heterogeneity in the error term. When we exclude this option, the treatment coefficient in column 4 is statistically significant at the 10% level.

waterfront properties are more aware of the coastal hazard risks, but the effect is still small and imprecisely identified.

Table 6-2 LHS variable- Log gross sale price - Affected Period 2012 – 2017

VARIABLE	(1) 100yr natural	(2) 100yr managed	(3) 50yr natural	(4) 50yr managed
Affected	0.121***	0.140***	0.135***	0.101***
	(0.0139)	(0.0148)	(0.0176)	(0.0283)
Post disclosure	-0.0139	-0.0145	-0.0161	-0.0155
	(0.0157)	(0.0157)	(0.0156)	(0.0157)
Post*Affected	-0.00183	-0.0145	-0.00660	-0.0594
	(0.0206)	(0.0223)	(0.0294)	(0.0527)
Floor area	0.00395***	0.00394***	0.00395***	0.00398***
	(0.000170)	(0.000170)	(0.000171)	(0.000173)
Site area	0.000206***	0.000209***	0.000201***	0.000202***
	(0.0000346)	(0.0000346)	(0.0000346)	(0.0000348)
Good interior	0.0317***	0.0316***	0.0318***	0.0307***
	(0.00614)	(0.00614)	(0.00612)	(0.00614)
Poor interior	-0.0352***	-0.0344***	-0.0340***	-0.0305***
	(0.0113)	(0.0113)	(0.0113)	(0.0114)
Good exterior	0.0459***	0.0468***	0.0476***	0.0501***
	(0.00544)	(0.00542)	(0.00543)	(0.00542)
Poor exterior	-0.133***	-0.132***	-0.132***	-0.135***
	(0.0219)	(0.0219)	(0.0219)	(0.0220)
Cross lease (2 shares)	-0.0563***	-0.0558***	-0.0574***	-0.0557***
	(0.00838)	(0.00838)	(0.00840)	(0.00845)
Cross lease (3+)	-0.114***	-0.116***	-0.117***	-0.110***
	(0.0167)	(0.0167)	(0.0166)	(0.0170)
Slight sea view	0.387***	0.366***	0.435***	0.489***
	(0.0487)	(0.0489)	(0.0468)	(0.0481)

Moderate sea view	0.623***	0.602***	0.663***	0.757***
	(0.0487)	(0.0487)	(0.0490)	(0.0520)
Wide sea view	0.637***	0.607***	0.647***	0.775***
	(0.0496)	(0.0501)	(0.0495)	(0.0501)
Slight view *Distance	-0.0542***	-0.0510***	-0.0609***	-0.0688***
	(0.00773)	(0.00775)	(0.00752)	(0.00769)
Moderate view *Distance	-0.0817***	-0.0787***	-0.0865***	-0.0995***
	(0.00812)	(0.00813)	(0.00817)	(0.00856)
Wide view *Distance	-0.0784***	-0.0743***	-0.0789***	-0.0961***
	(0.00727)	(0.00733)	(0.00730)	(0.00746)
Constant	12.22***	12.21***	12.22***	12.21***
	(0.145)	(0.145)	(0.144)	(0.147)
Observations	8,436	8,436	8,436	8,436
Adjusted R^2	0.774	0.774	0.773	0.771

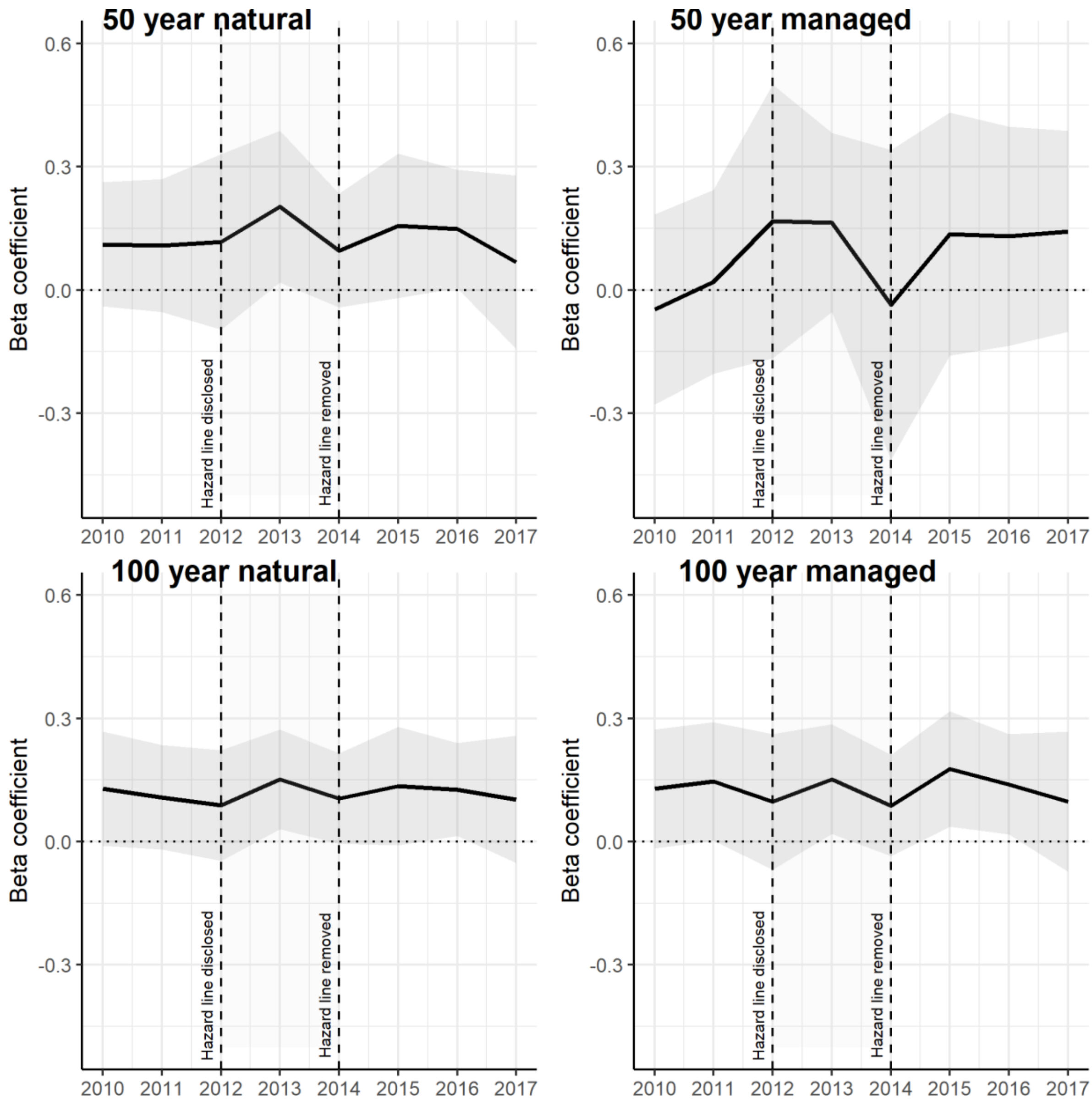
***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses

In addition to this benchmark specification, we estimate three alternative specifications (see Appendix Tables 1-3). In the first specification, we use the sale price per squared-meter as dependent variable in the regression. In the second, we estimate the same equation as in Table 6-2, but use the 'post' period as the period in which the risk warning was appended to the LIM (only September 2012 to October 2014). In the third iteration (Table 6-5), we only estimate the price of land, rather than the aggregate price of the property (which includes both the price of the land and the price of the dwelling). For the long-term horizons of the scenarios we examine (50-100 years), a large portion of property value comes from the value of the land (as the dwelling depreciates eventually becoming obsolete). We hypothesize that coastal erosion risks may therefore mostly affect the sale price through changing the valuation of the land. We separate the price of the land by deducting, from the sale price, the estimated value of the dwelling (see Appendix A for explanation of land value estimation). The results for all three alternative specifications, as shown in the appendix, are very similar to the benchmark regressions results. In none of the alternative specifications the estimates of the difference-in-difference effect is statistically significant. Similarly, the coefficient for the 50-year managed risk zone (the highest risk) shows the most decline in sale prices, though still a statistically insignificant one.

Next, we examine effects of coastal hazard risk on property prices over time by estimating annual regressions for each hazard group.[141] The results are shown in Figure 6-2. We observe that the coefficients of the $Affect_i$ is consistently above 0 (ranging between 0.1 and 0.2). Only for the 50-year managed group, the effect briefly deeps below 0 in 2014. However, due to the confidence intervals, this effect is statistically insignificant. Overall, given the known hazard risks, buyers are still willing to pay the same premium for these coastal properties, and appear to largely ignore the new information they received in 2012. In short, the erosion risk information being placed in the LIM reports seemed to have had little effect on property pricing.

[141] The $Post_i$ variable and interaction term are excluded in these specifications.

Figure 6-2 Effect of coastal hazard risk on property price over time



(Note: the 95% confidence interval is shown as the grey-colored ribbon.)

We also estimated spatial regression models to control for the spatial dependencies in the pricing of properties (i.e., property prices are affected by prices of property transactions in the immediate neighborhood; see Appendix B for details of the specifications). Table 6-6 in the appendix provides these results. Supporting the above findings, we find that the effect of the hazard information is insignificant across different models, specifications and across treated groups. The estimated spatial autoregressive (ρ) and autocorrelation (λ) coefficients are statistically significant; and the sale price of a property is positively influenced by neighbouring properties' sale prices.

6.6. Conclusions

One interpretation of Horace's *carpe diem* full dictum is not hedonistic; he asks his readers not to ignore the future and not to trust that everything is going to fall into place without deliberate action. Our evidence seems to suggest that rather than heeding that second part of Horace's counsel, the buyers of homes on the Kapiti Coast are 'seizing the day' and largely ignoring the future risks to their properties.

In New Zealand, the average time that a family owns a property is 6 years (Quotable Value, 2012). As such, it might not be that surprising that prospective buyers are ignoring these long-term risks. On the other hand, this assumes that future buyers will continue to ignore this risk so that selling later will not involve a significant loss, not unlike a scheme that Charles Ponzi would have approved. The evidence presented here suggested that this is indeed the case.

It might be the case, however, that only some people are ignoring these risks, and given the characteristics of real estate markets, the number of people 'who care' is not yet enough to be observable in a relatively limited geographical area (Bakkensen & Barrage, 2017). The evidence from elsewhere suggests that people do consistently ignore these types of risks until they became salient through some external event. Storey and Noy (2017) suggest that such an external event might be a strong storm surge—a disaster—that destroys a significant number of properties somewhere (maybe elsewhere in New Zealand) or a coordinated decision by private insurance companies or the government to stop insuring this erosion/storm-surge hazard. Whether, or when, that actually happens is, of course, impossible to predict.

Appendix A - Methodology - Land sale price

We have: $Land\ price_i = Gross\ price_i - Dwelling\ price_i$

Given i is an individual property transaction. However, we do not observe the dwelling sale price for each transition. We estimate the $Dwelling\ price_i$ variable using Quotable Value (QV) rated value for each property. The QV is the assessed value of the property that is then used for assessing property taxes, and is frequently used as an indicator of possible price during house sales; it is provided separately for the value of the land and the dwelling. It is computed as follow:

$$Dwelling\ price_{it} = QV\_Dwelling\ value_{ir}\ \frac{Coefficient_i^{sale\_year(t)}}{Coefficient_i^{rate\_year(r)}} \quad [A1]$$

The sale year (t) is frequently different from the year in which the property was assessed (QV property assessments are usually done every three years). We therefore convert the dwelling price to year (t) using the coefficients of the sale year (t) and QV rated year (r) dummies from our hedonic regression model.

Appendix B - Methodology - Spatial regression

We implement three different spatial regression models including Spatial Autoregressive Model (SAR), Spatial Error Model (SEM) and Spatial Autocorrelation Model (SAC). We employ spatial panel Maximum Likelihood estimation for the set of regression models with robust-standard error as described below.

(SAR) $Y_i = \alpha + \rho W Y_i + \beta X_i + \varepsilon_i$ [A2]

(SEM) $Y_i = \alpha + \beta X_i + \vartheta_i$ where $\vartheta_i = \lambda W \vartheta_i + \varepsilon_i$ [A3]

(SAC) $Y_i = \alpha + \rho W Y_i + \beta X_i + \vartheta_{i,t}$ where $\vartheta_{i,} = \lambda W \vartheta_i + \varepsilon_i$ [A4]

In these models, there are two possible types of interaction effects among units: endogenous spatial interaction effects among the dependent variable (WY_i) and spatial interaction effects among the error terms ($W\vartheta_i$). The parameter ρ is the spatial autoregressive coefficient and λ are the spatial-response coefficients. W is the non-negative spatial weighting matrix ($N \times N$). It describes the spatial structure of the dependence between property locations in the sample. Here, we employ the inverse distance weighted matrix which is row-standardized. The elements ω_{ij} of matrix W show whether the properties i and j are spatially connected. We have $\omega_{ij} = {}^{1}/_{d_{ij}}$ for neighbouring properties given d_{ij} is the distance between properties i and j, otherwise $\omega_{ij} = 0$. When the distance is beyond a pre-determined level, we assume that there are no spatial effects.

Appendix Table

Table 6-3 Log price per squared-meter - Affected Period 2012 – 2017

VARIABLE	(1) 100yr natural	(2) 100yr managed	(3) 50yr natural	(4) 50yr managed
Affected	0.255***	0.298***	0.234***	0.166***
	(0.0250)	(0.0263)	(0.0291)	(0.0412)
Post	0.0156	0.0139	0.00774	0.00731
	(0.0242)	(0.0241)	(0.0242)	(0.0242)
Post*Affected	-0.0387	-0.0547	-0.0364	-0.0786
	(0.0325)	(0.0346)	(0.0425)	(0.0587)
Building floor area	0.00156***	0.00154***	0.00159***	0.00165***
	(0.000371)	(0.000370)	(0.000372)	(0.000376)
Site area	0.000916***	0.000924***	0.000908***	0.000906***
	(0.0000791)	(0.0000791)	(0.0000797)	(0.0000797)
Good interior quality	0.0239*	0.0237*	0.0239*	0.0214
	(0.0132)	(0.0132)	(0.0133)	(0.0134)
Poor interior quality	-0.0515*	-0.0501*	-0.0459	-0.0390
	(0.0298)	(0.0298)	(0.0298)	(0.0299)
Good exterior quality	0.0202*	0.0217**	0.0246**	0.0293***
	(0.0109)	(0.0109)	(0.0109)	(0.0110)
Poor exterior quality	-0.0799**	-0.0793**	-0.0816**	-0.0865**
	(0.0384)	(0.0383)	(0.0384)	(0.0386)
Cross lease (2 shares)	-0.111***	-0.110***	-0.112***	-0.109***
	(0.0205)	(0.0205)	(0.0205)	(0.0206)
Cross lease (3+)	-0.236***	-0.240***	-0.239***	-0.225***
	(0.0437)	(0.0435)	(0.0433)	(0.0451)
Slight sea view	0.625***	0.575***	0.753***	0.843***
	(0.101)	(0.102)	(0.0983)	(0.0982)
Moderate sea view	0.877***	0.826***	1.005***	1.156***
	(0.0719)	(0.0732)	(0.0757)	(0.0747)
Wide sea view	1.138***	1.068***	1.228***	1.441***

	(0.0806)	(0.0820)	(0.0834)	(0.0810)
Slight View*Distance	-0.0821***	-0.0747***	-0.100***	-0.114***
	(0.0173)	(0.0175)	(0.0170)	(0.0170)
Moderate View*Distance	-0.0930***	-0.0856***	-0.109***	-0.130***
	(0.0117)	(0.0118)	(0.0122)	(0.0121)
Wide View*Distance	-0.130***	-0.121***	-0.141***	-0.169***
	(0.0137)	(0.0139)	(0.0142)	(0.0140)
Constant	10.51***	10.51***	10.52***	10.51***
	(0.520)	(0.519)	(0.520)	(0.522)
Observations	7975	7975	7975	7975
Adjusted R-squared	0.473	0.474	0.470	0.466

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses

Table 6-4 Log gross sale price - Affected Period 2012 - 2014

VARIABLE	(1) 100yr natural	(2) 100yr managed	(3) 50yr natural	(4) 50yr managed
Affected	0.118***	0.135***	0.129***	0.103***
	(0.0132)	(0.0142)	(0.0166)	(0.0268)
Post	0.0156	0.0157	0.0158	0.0209
	(0.0143)	(0.0143)	(0.0143)	(0.0145)
Post*Affected	0.00731	-0.00293	0.0211	-0.0957
	(0.0233)	(0.0255)	(0.0358)	(0.0676)
Building floor area	0.00395***	0.00394***	0.00395***	0.00398***
	(0.000170)	(0.000170)	(0.000171)	(0.000173)
Site area	0.000206***	0.000209***	0.000200***	0.000202***
	(0.0000346)	(0.0000346)	(0.0000346)	(0.0000348)
Good interior quality	0.0317***	0.0317***	0.0318***	0.0308***
	(0.00614)	(0.00613)	(0.00612)	(0.00612)
Poor interior quality	-0.0350***	-0.0341***	-0.0336***	-0.0303***
	(0.0113)	(0.0113)	(0.0113)	(0.0114)
Good exterior quality	0.0456***	0.0465***	0.0474***	0.0498***
	(0.00544)	(0.00543)	(0.00544)	(0.00543)
Poor exterior quality	-0.132***	-0.132***	-0.132***	-0.136***
	(0.0219)	(0.0219)	(0.0219)	(0.0220)
Cross lease (2 shares)	-0.0564***	-0.0559***	-0.0575***	-0.0555***
	(0.00839)	(0.00839)	(0.00840)	(0.00846)
Cross lease (3+)	-0.114***	-0.116***	-0.117***	-0.110***
	(0.0167)	(0.0167)	(0.0166)	(0.0170)
Slight sea view	0.388***	0.367***	0.435***	0.491***
	(0.0488)	(0.0491)	(0.0470)	(0.0483)
Moderate sea view	0.623***	0.602***	0.661***	0.755***
	(0.0486)	(0.0487)	(0.0489)	(0.0519)
Wide sea view	0.636***	0.608***	0.646***	0.771***
	(0.0496)	(0.0501)	(0.0493)	(0.0502)

Slight View*Distance	-0.0542***	-0.0511***	-0.0609***	-0.0691***
	(0.00775)	(0.00778)	(0.00754)	(0.00772)
Moderate View*Distance	-0.0817***	-0.0786***	-0.0862***	-0.0991***
	(0.00811)	(0.00812)	(0.00816)	(0.00854)
Wide View*Distance	-0.0782***	-0.0742***	-0.0786***	-0.0954***
	(0.00726)	(0.00732)	(0.00728)	(0.00748)
Constant	12.21***	12.21***	12.21***	12.20***
	(0.147)	(0.146)	(0.146)	(0.149)
Observations	8436	8436	8436	8436
Adjusted R-squared	0.774	0.774	0.773	0.771

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses

Table 6-5 Log land price - Affected Period 2012 – 2017

VARIABLE	(1) 100yr natural	(2) 100yr managed	(3) 50yr natural	(4) 50yr managed
Affected	0.109***	0.122***	0.130***	0.152***
	(0.0189)	(0.0206)	(0.0240)	(0.0389)
Post	0.0138	0.0133	0.0122	0.0139
	(0.0200)	(0.0200)	(0.0200)	(0.0200)
Post*Affected	0.0207	0.00796	0.0187	-0.0674
	(0.0243)	(0.0259)	(0.0316)	(0.0514)
Building floor area	0.00833***	0.00833***	0.00833***	0.00830***
	(0.000232)	(0.000231)	(0.000231)	(0.000232)
Site area	0.000215***	0.000217***	0.000209***	0.000211***
	(0.0000455)	(0.0000454)	(0.0000451)	(0.0000450)
Good interior quality	0.0291***	0.0290***	0.0292***	0.0282***
	(0.00719)	(0.00718)	(0.00718)	(0.00720)
Poor interior quality	0.0251	0.0262	0.0264	0.0294*
	(0.0174)	(0.0174)	(0.0174)	(0.0174)
Good exterior quality	0.0487***	0.0497***	0.0503***	0.0531***
	(0.00729)	(0.00728)	(0.00728)	(0.00727)
Poor exterior quality	-0.151***	-0.151***	-0.151***	-0.153***
	(0.0324)	(0.0324)	(0.0322)	(0.0321)
Cross lease (2 shares)	-0.0168*	-0.0162*	-0.0179*	-0.0174*
	(0.00944)	(0.00941)	(0.00941)	(0.00942)
Cross lease (3+)	-0.0876***	-0.0890***	-0.0914***	-0.0853***
	(0.0166)	(0.0166)	(0.0165)	(0.0169)
Slight sea view	0.380***	0.366***	0.419***	0.450***
	(0.0656)	(0.0656)	(0.0638)	(0.0630)
Moderate sea view	0.627***	0.614***	0.656***	0.730***
	(0.0557)	(0.0561)	(0.0569)	(0.0583)
Wide sea view	0.794***	0.775***	0.792***	0.887***
	(0.0588)	(0.0598)	(0.0590)	(0.0592)

Slight View*Distance	-0.0514***	-0.0493***	-0.0568***	-0.0613***
	(0.00983)	(0.00983)	(0.00960)	(0.00950)
Moderate View*Distance	-0.0799***	-0.0780***	-0.0832***	-0.0933***
	(0.00860)	(0.00865)	(0.00877)	(0.00901)
Wide View*Distance	-0.102***	-0.0997***	-0.101***	-0.114***
	(0.00929)	(0.00940)	(0.00937)	(0.00944)
Constant	8.722***	8.719***	8.726***	8.717***
	(0.145)	(0.144)	(0.143)	(0.146)
Observations	8436	8436	8436	8436
Adjusted R-squared	0.596	0.596	0.595	0.593

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parentheses.

Table 6-6 Spatial Regressions - Log gross sale price - Affected Period 2012 - 2017

	SAR				SEM				SAC			
	100yr natural	**100yr managed**	**50yr natural**	**50yr managed**	**100yr natural**	**100yr managed**	**50yr natural**	**50yr managed**	**100yr natural**	**100yr managed**	**50yr natural**	**50yr managed**
Direct	-0.0021	-0.0179	-0.0123	-0.0511	0.0089	-0.0039	-0.0030	-0.0039	0.0066	-0.0068	-0.0143	-0.0428
	(0.0156)	(0.0164)	(.0203)	(0.0339)	(0.0152)	(0.0160)	(0.0160)	(0.0160)	(0.0153)	(0.0161)	(.0198)	(0.0336)
Indirect	-0.0005	-0.0044	-0.0031	-0.0134					0.0005	-0.0005	-0.0013	-0.0045
	(0.0039)	(0.0041)	(0.0051)	(0.0089)					(0.0013)	(0.0013)	(.0018)	(0.0036)
Total impact	-0.0026	-0.0223	-0.0155	-0.0646	0.0089	-0.0039	-0.0039	-0.0039	0.0071	-0.0074	-0.0156	-0.0473
	(0.0195)	(0.0205)	(.0255)	(0.0429)	(0.0152)	(0.0160)	(0.0160)	(0.0160)	(0 .0166)	(0.0174)	(.0216)	(0.0371)
Spatial												
ρ	0.206***	0.205***	0.209***	0.215***					0.0821***	0.0787***	0.0850***	0.0968***
	(0.0101)	(0.0101)	(0.0101)	(0.0101)					(0.0161)	(0.0162)	(0.0161)	(0.0159)
λ					0.349***	0.348***	0.354***	0.357***	0.274***	0.277***	0.276***	0.268***
					(0.0142)	(0.0142)	(0.0142)	(0.0143)	(0.0212)	(0.0211)	(0.0213)	(0.0214)

***/**/* Indicating the significance levels of respectively 1%, 5% and 10%. Robust standard errors are shown in parenthesis.

Appendix Figure

Figure 6-3 Property transactions in Kapiti Coast

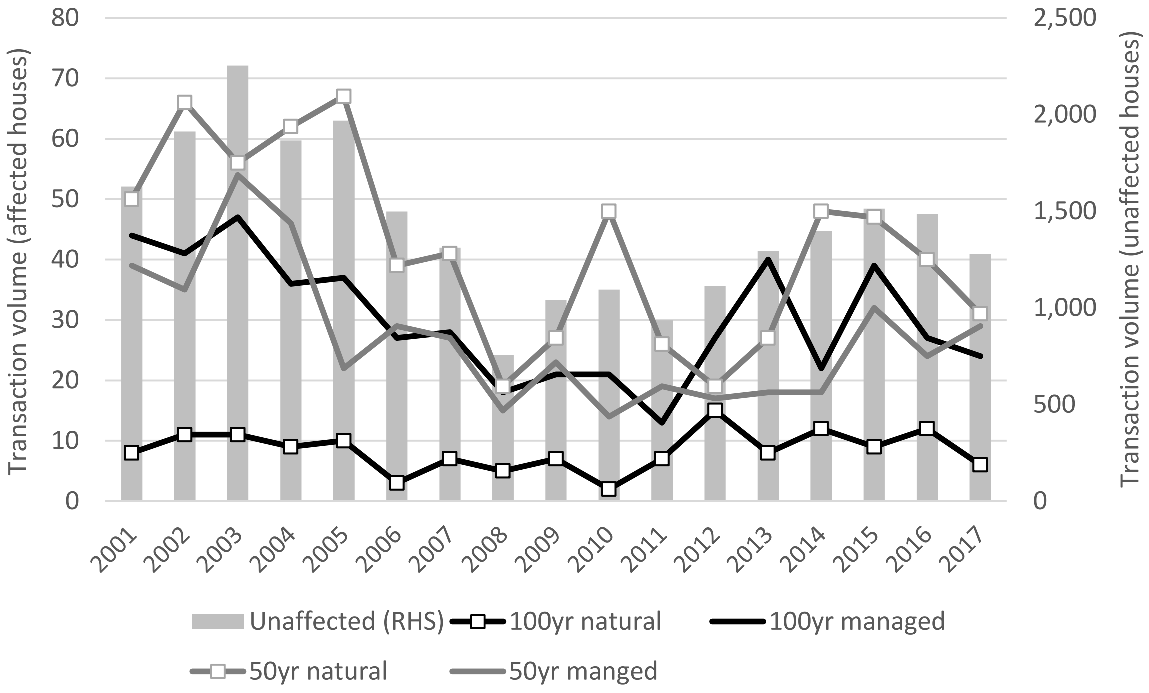
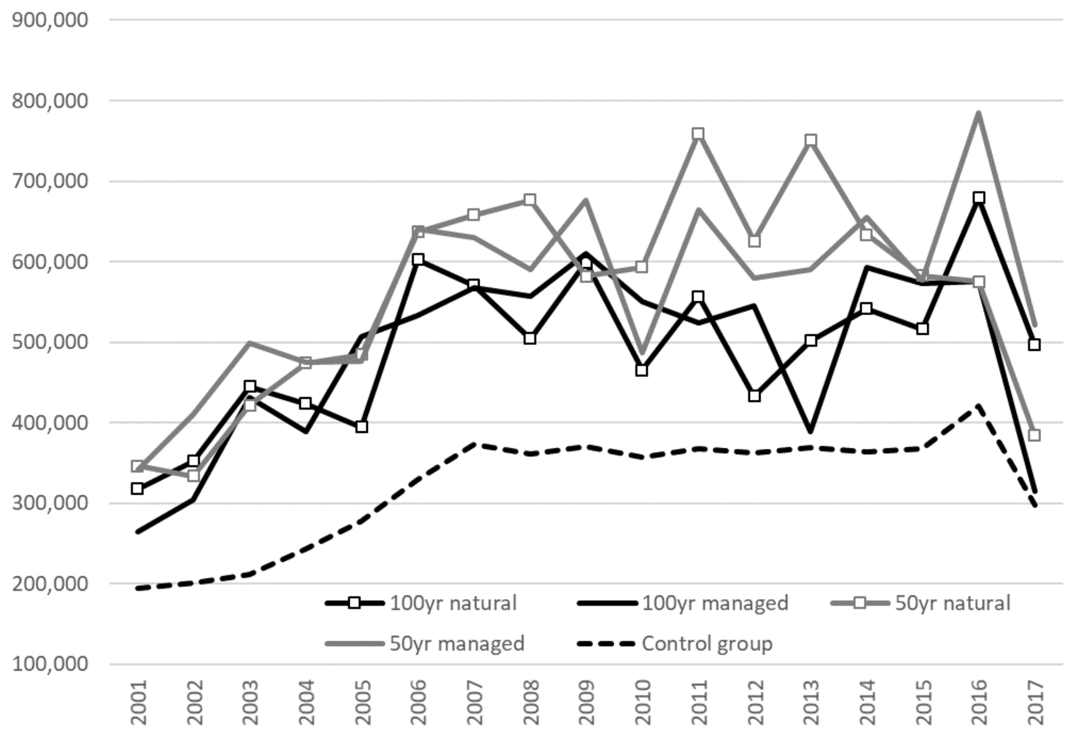


Figure 6-4 Mean Gross Sale Price Over Time (NZ$)



Chapter 7

Conclusion

The primary objective of this dissertation is to provide insights about New Zealand's earthquake insurance system, about household recovery post-disaster and more generally about disaster risk perception. Ultimately, the aim of the thesis is to produce research outputs that can be readily applied for policy decisions. The findings and implications of the empirical studies included in this dissertation are summarized below.

Chapter 2 emphasizes the importance of insurance in pooling and transferring earthquake risk. Disaster insurance requires government's supports in order to operate effectively. We conclude that insurance can provide a financial buffer for catastrophic risks and help to stimulate the recovery post-event, and identify some of the barriers for its further use.

Chapter 3 describes in detail the Canterbury earthquake sequence in 2010-2011. The event is then used as a scenario for the Japanese and Californian earthquake insurance schemes. Results of this scenarios demonstrate the consequences of having low insurance penetration rate to the affected homeowner and to the economy after a major disaster event. The chapter also explains the shortcomings of high insurance take-up rate in New Zealand post-earthquakes. These include the speed and the efficiency of the insurance claim payment process.

Chapter 4 quantifies how earthquake damage reduces the light radiance immediate after the Canterbury earthquake. More importantly, we find that the insurance payments contributed significantly to the recovery of local residential areas. We further find that prolonged settlement delays reduce the benefits associated with the insurance payments. In addition, there are positive spillover effects of cash payment for the recovery of surrounding neighborhoods.

Chapter 5 examines the households' choice regarding the property buy-out program in the Christchurch Residential Red Zones (RRZ). The RRZ homeowners could choose either to accept the Crown offer for their properties or receive claim payment for the building damage from their insurer. We find that the homeowners more frequently chose the Crown option when their property had high improvement value or suffered high earthquake damage. Moreover, we find that the homeowner's choice was also influenced by the choice of neighboring households.

Chapter 6 investigates home-buyers' perception of coastal hazard risk in the Kapiti Coast district. We find that these buyers ignore erosion risk associated with projected sea level rise, and there is no significant effect of public disclosure of the hazard on the property sale price.

There are a number of future projects that we plan to carry out after submitting this thesis. Firstly, a project aims to quantify the effect of the Kaikoura earthquake event (November 2016) to local economic activity, transportation and tourism. Secondly, related to Chapter 4, we can use individual data from Integrated Data Infrastructure (IDI) to identify the recovery process post-CES. We examine how the earthquakes affected spending and saving patterns and how insurance payment contributes to recovery process. Thirdly, related to Chapter 5, we expect to have the Red zone property data merged with the IDI. This will provide us the characteristics of affected households at individual level which may drive the option choice. And this new information will shed the light on how homeowner's choice affects her recovery post- buyout process. Fourthly, related to chapter 6, we can compare the effect of public disclosure of coastal erosion lines in other areas such as in Christchurch and Banks Peninsula with our case study in Kapiti Coast. We can investigate how this climate change warning affects the insurance premium and the property market in New Zealand context. Overall, there are many research topics that we can pursue potentially based on this PhD thesis.

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