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ORIGINAL PAPER

# Before a Fall: Impacts of Earthquake Regulation on Commercial Buildings

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**Abstract** We test whether the major earthquakes in Christchurch (Canterbury, New Zealand) affected prices of earthquake-prone commercial buildings in Wellington, a city that was directly unaffected by the disaster. Specifically, we test whether official declaration of a Wellington building as earthquake-prone (with a requirement for remediation to minimum earthquake code standards) had an effect on sale price relative to similarly earthquake-prone (but yet-to-be-declared) buildings. We find that the price discount accompanying an earthquake-prone declaration in the CBD averages 45% whereas there is no observable discount on buildings yet-to-be-declared as earthquake-prone. Sale prices of currently-declared earthquake-prone commercial buildings in the suburbs also fell, but not as markedly. The sale probability of officially declared earthquake-prone buildings in Wellington rose markedly after the Christchurch earthquakes unlike the sale probability of yet-to-be-declared earthquake-prone buildings which fell slightly, reflecting buyer caution about such buildings. This pattern is indicative of forced sale of buildings following an official earthquake-prone declaration.

**Keywords** Earthquake-prone buildings · Commercial property · Property prices · Sales probability

**JEL Classification** Q54 · R33 · R38

## Introduction

We examine the effects of the devastating Christchurch (Canterbury, New Zealand) earthquakes on commercial building prices in an earthquake-prone (but directly unaffected) city,

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Wellington. Specifically, we examine the effects of the Christchurch earthquakes on Wellington commercial building prices in the presence of regulations and building codes that resulted in some buildings being officially declared as earthquake-prone. Several papers have examined the impacts of natural and industrial disasters on housing markets, both in areas affected by the disaster and in unaffected areas.[1] In addition, studies have examined the effects of floods on agricultural properties and houses in flood-prone areas.[2] However, there is little or no analysis of the effects of a major natural disaster on the market for commercial buildings, especially those that were not directly affected by the disaster. Our paper, which utilises official records on earthquake-prone buildings coupled with market sales price data, provides the first such study.

Our major focus is to examine the post-earthquake price impacts on commercial buildings of a public policy that declares certain buildings to be earthquake-prone, with accompanying requirements on owners to raise the structural integrity of the building. By utilising the timing of official earthquake-prone notices, we can distinguish whether the policy of declaring a building earthquake-prone has a price effect relative to buildings that are not yet declared earthquake-prone but which subsequently receive that status.

An earthquake of magnitude 7.1 on the Richter scale struck Christchurch on 4 September 2010. An even more damaging aftershock struck the central city on 22 February 2011 killing 185 people. Subsequent aftershocks caused further damage over the next year. The city's central business district (CBD) remained cordoned off for more than 2 years and approximately 16,000 properties were severely damaged. The Treasury (2013) estimated that total investment associated with the city's rebuild would amount to around 20% of the country's GDP. The earthquakes badly damaged many older brick and mortar buildings, many of which were commercial buildings in the CBD.

Risk of collapse or severe damage amongst brick and unreinforced masonry buildings in earthquakes had been shown repeatedly in earlier New Zealand earthquakes including the 1848 Marlborough earthquake and the 1855 Wairarapa earthquake, both of which devastated the fledgling city of Wellington. Further major earthquakes within the country (especially the 1929 Murchison earthquake, the 1931 Napier earthquake and the 1942 Wairarapa earthquakes, all of which were between 7.2 and 8.2 on the Richter scale) again exposed the risk posed by brick and unreinforced masonry buildings. Nevertheless, further such buildings were built throughout New Zealand, even in Wellington, a city which had been established both scientifically and through experience as an earthquake-prone city (Thornton 2010).

Consistent with the cited literature, we hypothesise that a major earthquake, such as in Christchurch, caused a re-evaluation of the danger posed by earthquake-prone buildings elsewhere, especially in an earthquake-prone city such as Wellington. Given the devastation to commercial buildings in Christchurch, we hypothesise that this re-evaluation will have impacted on prices of earthquake-prone commercial buildings. We test whether public policy intervention by local and central government had an additional effect on commercial building prices through formal declaration of buildings that fell below a certain safety threshold as "Earthquake-Prone Buildings".

The evaluation of the effect of this public policy intervention is important since the private sector was quite capable of conducting engineering assessments of building standards that

[1] Murdoch et al. (1993); Naoi et al. (2009); Timar et al. (2014); Bléhaut (2015).

[2] Bin and Polasky (2004); Bin and Kruse (2006); Samarasinghe and Sharp (2010); Bin and Landry (2013); Gallagher (2014).

could reach similar conclusions as the authorities on building strength in relation to existing earthquake-related building codes. If the public policy intervention is found to have had an additional effect, the implication is that the private sector's internalisation of costs associated with such buildings differed from the costs perceived by the public authorities. We make no judgement as to whether one set of perceptions is more appropriate than the other, but establishing whether such a disparity exists is an important step in understanding the role and effects of public policy intervention.

## Background

### Earthquake-Prone Buildings

National building design standards for earthquake safety were first introduced in New Zealand following the 1931 Napier earthquake although, reflecting its prior earthquake experience, Wellington City already had some basic safety requirements before 1931. The standards have undergone major improvements over time, and many buildings that exist today fail to meet modern design standards despite meeting the (lesser) standards that prevailed when they were built.

In 2004, the government enacted legislation (the Building Act 2004) directed at improving the seismic performance of the existing building stock. A building is considered earthquake-prone if it is less than one third of the strength required for a new building under current design standards. These buildings have a significantly higher risk of serious damage or collapse during an earthquake causing injury, death or damage to other property.

The responsibility for developing a strategy to deal with earthquake-prone buildings rests with local councils. In Wellington, the City Council prioritises the assessment and strengthening of buildings based on importance for community function, building age and condition (WCC 2009). Owners of buildings found to be earthquake-prone by a preliminary assessment have 6 months to dispute the finding, typically by providing a private structural engineer's report with evidence to the contrary.

Buildings that have been determined as earthquake-prone must be upgraded to at least one third of the new building standard, or they must be demolished. For most buildings, the maximum timeframe for undertaking strengthening work (or demolition) ranges from 10 to 20 years, based on the building's priority level. The costs of this work are usually fully borne by the building's owner (with limited opportunities for assistance to owners of heritage buildings). If structural upgrading to the appropriate seismic standard is not carried out within the required timeframe, the Council can take legal action to prohibit anyone from using or occupying the building and, eventually, to force the owner to strengthen or demolish the building (WCC 2009).

In Wellington, the database of potentially earthquake-prone buildings is freely available (and easily accessible) to the public. For the information of people entering and using an affected building, owners must clearly display the earthquake-prone notice on site. In addition, the earthquake-prone classification is recorded in Land Information Memoranda issued for the building which are routinely requested by prospective property buyers before a transaction takes place.

Unlike residential buildings which are covered by a public earthquake insurance scheme, there is no public insurance scheme for commercial buildings. Owners of commercial buildings must seek insurance against earthquake damage from private sector insurance companies. Storey and Noy (2017) document loss of insurance cover for earthquake-prone buildings following the Christchurch earthquakes accompanied by a 'dramatic' rise in premiums for buildings that were insurable. Similarly, Brookie (2012) reported a large rise in earthquake insurance premiums following the Christchurch earthquakes, while Parker and Steenkamp (2012) show that insurance costs increased markedly for businesses following the earthquakes and that 'terms and conditions, such as excesses' (deductibles) also tightened. It is reasonable to infer from these studies that such tightenings for conditions and premiums were most severe for officially-declared earthquake-prone buildings.

Since the devastating earthquakes that struck Christchurch, public interest in seismic safety has sharply increased (WCC 2015), and evidence indicates that the rate of strengthening of commercial buildings has risen significantly in Wellington (Thomas et al. 2013).

## Hypotheses

With rational agents, the price of a commercial building should reflect the discounted flow of future rents less costs. Rents will be positively related to sought-after building attributes and negatively related to adverse attributes, of which being earthquake-prone is one candidate. Consistent with this observation, Filippova and Rehm (2017) find evidence that office rents in Wellington are positively related to the building's seismic strength.[3] Furthermore, future costs associated with a declared earthquake-prone building are likely to be higher, ceteris paribus, than for other buildings owing to the owner's duty to upgrade the building to at least one third of the new building standard. Similarly, a building that is expected to be declared earthquake-prone in the near future should be predicted to incur an equivalent remediation cost and so should face a similar price discount to an already declared earthquake-prone building.

We hypothesise, therefore, that with purely rational agents prices will be discounted for commercial buildings that are: (a) declared to be earthquake-prone, or (b) expected to be declared earthquake-prone in future. Given this overarching hypothesis (based on rational agents), we test for several specific effects.

First, we test whether the discount for earthquake-prone buildings increased following the Christchurch earthquakes. An increase in the discount may reflect a rational response to changes in the commercial building insurance market if insurers increased their building excess (deductible) and/or increased the premium on earthquake-prone buildings relative to seismically strong buildings (as appeared to have occurred after the Christchurch earthquakes). A more 'behavioural economics' reason may be that the salience of earthquake issues was heightened after the earthquakes and transactors in the commercial property market became more averse to earthquake risks as a result of this heightened risk awareness – despite an unchanged probability of an earthquake in Wellington. Research into housing markets in the Wellington Region showed an immediate drop in prices of vulnerable houses (relative to less vulnerable houses) following the first Christchurch earthquake (Timar et al. 2014), apparently reflecting increased salience of earthquake risks.

Second, we test whether the same discount applies to buildings that are already declared earthquake-prone and to those that are subsequently declared (post-sale) as earthquake-prone

[3] Anecdotal evidence indicates that many corporate boards refuse to house their staff in buildings with poor earthquake ratings lest an earthquake occur and they are held legally or ethically responsible for any resulting deaths or injuries.

but which had not been declared earthquake-prone at the time of sale. We again differentiate this effect between pre- and post-Christchurch earthquake. As discussed above, rational, fully-informed, buyers should take account of the likely future earthquake-prone status of buildings when purchasing a commercial building, so there should be little or no difference in discount between currently-declared earthquake-prone buildings and future-declared earthquake-prone buildings.

One reason why future-declared earthquake-prone buildings may sell at a lesser discount than currently-declared earthquake-prone buildings is imperfect information. It may be difficult for prospective buyers and their engineering consultants to determine if the City Council will assess a building to be earthquake-prone or not. For instance, a building found by Council to be at 30% of current code will be declared earthquake-prone whereas one at 35% of code will not be, but an independent engineer may find it difficult to differentiate between the two levels.[4] We have no data on the assessed degree of code compliance of each building so we cannot undertake, for instance, a regression discontinuity analysis. Instead, we test whether the Council's decision to declare a building earthquake-prone changes its discount in the market, possibly as a result of resolving any uncertainty that may exist as to its official degree of code compliance.

A second form of information deficiency relates to the rental market. Firms may refuse to locate their staff in an officially-declared earthquake-prone building (which is publicly known), but be less averse to doing so in an apparently similar building that has not been declared earthquake-prone. Again, the official declaration of a building as earthquake-prone resolves this source of uncertainty while at the same time lowering the rent.

A third set of reasons that a currently-declared earthquake-prone building may sell at a discount relative to a future-declared earthquake-prone building relates to behavioural biases of potential purchasers. Meyer and Kunreuther (2017) document a range of biases – including myopia bias, amnesia bias, optimism bias and simplification bias – that cause many people to underprepare for disasters. These biases only need to operate for a subset of potential purchasers (including the ultimate purchaser) for the price of an undeclared (but earthquake-prone) building to be above that of an otherwise identical currently-declared earthquake-prone building. In essence, the unlucky purchaser is subject to a winners curse as a result of their behavioural biases when purchasing the property.

With our data we cannot distinguish whether any difference in price between currently-declared and future-declared earthquake-prone buildings is due to rational reasons or to behavioural biases. However some indication may be gleaned from our modelling also of the sale probability of different building types.

There is some evidence that the probability of sale of houses located near certain industrial plants declined following a major industrial accident in France (Bléhaut 2015). A similar response would imply that prospective buyers may be deterred from purchasing a commercial building that could in future be declared earthquake-prone, and so this may reduce the probability of sale. This effect may, however, be overridden in the case of current-declared earthquake-prone buildings. Owners of buildings that have been declared earthquake-prone have an obligation to bring the buildings up to one-third of current code or face the building remaining vacant or being demolished. This obligation could increase the probability of sale of an earthquake-prone building if the owner cannot finance the required reconstruction so

[4] Anecdotal evidence indicates that different engineers can report disparate results with respect to code-compliance.

becoming a forced seller.[5] We hypothesise that being declared earthquake-prone (especially after a major earthquake when there may be tighter enforcement of the legal requirement to upgrade the building promptly) will increase the probability of sale of a building with current earthquake-prone status.

By contrast, there should be no forced sale for a building that is not currently-declared to be earthquake-prone but is later declared prone. At this stage, there is no obligation on the owner to upgrade and hence no immediate increase in the need for an existing owner to sell. Instead, reflecting the Bléhaut (2015) results, the probability of sale may decline after an earthquake if prospective purchasers become more wary about purchasing older or less well-built commercial buildings.

Econometrically, a change in the probability of sale of a building creates a selection (endogeneity) issue since the properties that are sold are not a random sample of all commercial properties. *Ex ante*, we have no prior expectation as to whether or how such a selection issue could affect our estimates. In section 4, we show that (current- and future-) declared earthquake-prone buildings look similar to each other across key characteristics, implying that there does not appear to be a selection issue related to the timing of earthquake-prone notices based on observable characteristics. In addition, as expected, current- and future-declared earthquake-prone buildings together look quite different to buildings that are not declared earthquake-prone. However, these results cannot provide complete assurance that there is no selection bias which could instead be based on unobservable characteristics.

One way to address this factor would be to estimate a Heckit system involving a probability of sale equation plus the sale price structural equation (with the addition of the inverse Mills ratio from the sale probability equation). However, (unless one were to rely purely on a functional form assumption) this procedure requires at least one instrument in the sale probability equation that does not affect sale price. We have no such available instrument. We therefore present the sale price equation and the sale probability equation separately and use the results from the latter to aid interpretation of results from the sale price equation.

We discuss our modelling approach in section 3, and discuss the data in the subsequent section. Section 5 presents results for both the sale price equation and the sale probability equation. Brief conclusions are contained in section 6.

## Modelling Approach

We estimate separate hedonic sale price and probability of sale models, recognising that we have insufficient data to perform a Heckman correction. The hedonic approach to measuring quality-adjusted prices for differentiated products grew out of the pioneering work of Rosen (1974). It has since been applied frequently to the measurement of house prices. In Hill's (2013) survey article of hedonic house price modelling he notes that housing is an "extreme case of differentiated product" since every house is different.

The same observation applies to commercial buildings. With respect to the latter, Diewert et al. (2015) note that the hedonic regression approach, while data intensive, is probably the most efficient method for using available commercial building sales data to decompose prices into the value of land and the values for each structural attribute of properties. They analyse the

[5] Grimes and Hyland (2015) show that binding credit constraints existed in New Zealand following the Global Financial Crisis which coincides with the post-earthquake period.

impacts that varying depreciation rates and (endogenously chosen) length of life of the commercial building structure have on the value of a commercial building. In our case, the declaration of a building as earthquake-prone has two relevant effects: (i) it imposes an explicit duty to remediate the building which can be considered equivalent to an exogenously imposed increase in building depreciation, and (ii) it may bring forward a decision to demolish the building so shortening the expected length of life of the existing structure. Each of these impacts reduces the current value of the building.

Diewert and Shimizu (2017) apply the hedonic regression approach to *appraised* values used by Real estate Income Trusts (REITs) for Tokyo office buildings. However a lack of data availability means that there are very few studies that apply the approach to the *sale prices* of commercial buildings. Our access to comprehensive building attributes data and matched sale price data enables us to break new ground in applying hedonic regression methodology to commercial buildings.

Our hedonic sale price equation is of the following semi-logarithmic form:

$$\ln\left(Price_i^t\right) = \alpha + \mu^t + \boldsymbol{\beta X_i} + \boldsymbol{\gamma Z_i} + \varepsilon_i^t \tag{1}$$

where $Price_i^t$ is the sale price of building $i$ sold in year $t$, $\alpha$ is a constant term, $\mu^t$ is a year dummy to reflect macroeconomic conditions (including overall commercial building price levels) at time of sale,[6] $\boldsymbol{X_i}$ is a set of non-earthquake-related building characteristics (with accompanying parameter vector, $\boldsymbol{\beta}$), $\boldsymbol{Z_i}$ is a set of earthquake-related building characteristics (with accompanying parameter vector, $\gamma$), and $\varepsilon_i^t$ is the residual term. Building characteristics include controls for decade of construction, land area, location (CBD or suburban), location interacted with land area, land use type, floor area interacted with land use type, building condition,[7] wall construction and roof construction. The results table in the appendix details all the variables within each of these control categories.

Earthquake-related variables include an indicator for whether the sale was post-first Christchurch earthquake (4 September 2010),[8] an indicator of whether the building had been declared earthquake-prone at time of sale, and an indicator of whether the building was subsequently declared earthquake-prone (but was not declared prone at time of sale). We additionally include each of the two earthquake-prone variables (i.e. current and future) interacted with the post-earthquake indicator. These interaction terms test whether the discount applied to (current or future) earthquake-prone buildings changed following the first Christchurch earthquake. Our key focus is on these interaction terms since they summarise the impact of the exogenous event (the Christchurch earthquakes) on the values placed on (current and future-declared) earthquake-prone buildings within Wellington. We anticipate that the two

[6] Sample size limits us to controlling for aggregate price trends rather than splitting up price trends prior to the earthquakes according to building type.

[7] The building condition variable is constructed from variables describing both the roof and the building condition.

[8] Given the presence of year dummies, the effect of this variable is estimated only on buildings sold pre- and post-earthquake in 2010. We tested whether we should instead use the date of the second (and more devastating) earthquake (11 February 2011). However, only one of the earthquake-prone buildings in our dataset was sold between the two earthquakes, and the impacts of changing the definition of this indicator variable were negligible.

post-earthquake interaction variables will have a negative effect on price as salience of earthquake-related issues rose following the first Christchurch earthquake.

For our empirical strategy regarding future-declared earthquake-prone buildings to work, it is necessary that building assessments had been completed (or nearly completed) by the end of our data period. Furthermore, there needs to be a mechanism by which buyers could become aware of the future earthquake-prone status of not-yet-assessed buildings. Both of these conditions are likely to be met. First, the council's expected timeframe to complete assessments (WCC 2015) indicated that, in theory, all potentially earthquake-prone buildings had been identified as such in our dataset. Second, conversations with both the WCC and Quotable Value New Zealand (a state-owned valuation company that is the source of some of our data) indicate that it is standard practice for prospective commercial property buyers to obtain a private engineering evaluation before purchase. It is therefore unlikely for an earthquake-prone building that had not yet been assessed by the council to be sold without the buyer's awareness of potential problems. As discussed in the previous section, however, engineering assessment is an imprecise science, and so there may be doubt as to whether buildings on the cusp of minimum code compliance will or will not be declared earthquake-prone in future.

Our focus is on the impacts of the earthquake-related interaction variables, so we confine our discussion to these estimated effects.[9] Consideration of the other hedonic estimates (which are provided in the results table in the Appendix Table 5) show that all estimates related to building characteristics have sensible properties, providing a sound basis for inferences of the earthquake effects.

Our probability of sale equation has the same form as eq. (1) except that it is estimated as a logit model with the dependent variable equal to 1 if the building is sold in that year, and equal to 0 otherwise. Reflecting the hypotheses in section 2.2, we expect that, following the earthquakes, being earthquake-prone at time of sale will have a positive effect on sales probability (potentially reflecting forced sales), whereas being declared earthquake-prone in future will be associated with a negative impact on sale probability (reflecting a reluctance of investors to purchase older, potentially earthquake-prone, buildings).

We cannot control for some potentially important factors. For example, the cost of strengthening differs widely depending on the building. This is expected to affect resale value and sale probability. Also, the existence and type of rental contract could have a major effect on the market value of a building: some contracts have ratchet clauses that prevent rent from dropping while others do not, but we have no data on vacancies and rents. These effects are therefore relegated to the residual term. We have no reason to believe that these effects will be systematically related to our variables of interest so their effect should be to decrease precision of the estimates rather than to introduce bias.

## Data

To estimate the model, we use data on property sales from Quotable Value New Zealand (QVNZ). Seismic strength information relating to specific properties is not

[9] Our data include only 2 sales of currently-declared earthquake-prone buildings prior to the Christchurch earthquakes so we do not attempt to interpret the pre-earthquake coefficients.

recorded in a way that can be extracted from the QVNZ property database. Instead, we use a dataset of earthquake-prone building assessments from the Wellington City Council (WCC) and merge information on building status to that on property sales. Records in the two datasets may not correspond exactly. Whereas records in the sales data represent rating (property tax) units, the earthquake-prone building registry is linked to survey properties which are based on Land Information New Zealand (LINZ) parcels.

The sales dataset from QVNZ contains Wellington properties classified as commercial with sale dates ranging from early 1973 to June 2015.[10] The time distribution of sales is uneven with nearly 90% of sales in the raw dataset taking place in the last 18 years. We focus on observations since 1998 and drop all sales prior to that year. Each observation includes the net sale price and the date of sale along with a range of variables that characterise the transaction and the property. We use information on sale tenure and type to filter for freehold, arms-length, open-market sales that can be matched with the rating unit information recorded in the district valuation roll (LINZ 2010). Transactions that do not meet these conditions are discarded.

We also have access to the assessed value for property tax purposes (at the time of the sale) of each property and to several variables that describe its age, size, construction type, condition, general location and use. Based on these, we create rules to perform additional data cleaning by dropping observations where there are indications that the sale did not involve a building, for instance for vacant lots or car parks.

Properties in the sales dataset are identified by a valuation reference number, a unique identifier for valuation purposes. It usually comprises two parts, a roll number and an assessment number which collectively define a parent record. When the valuation reference also includes an assessment suffix, it defines a part record. This allows rates to be split across different uses. A part record can be a unit within a building or a detached building on the land parcel - there is no attribute to show which. It is therefore not clear whether part records should inherit the earthquake-prone classification of their parent record. Moreover, all part records are entered with a zero land area, which is a key variable in our estimation. For these reasons, we discard part records from our dataset and only use observations on parent records.

Wellington City Council provided a dataset of buildings that have, at any time, been assessed as earthquake-prone. The publicly available version of this dataset contains a list of currently-declared earthquake-prone buildings. We also have the historical status for buildings that were regarded as earthquake-prone in the past, but have already been taken off the list (for example because they have been remediated), and we have access to some additional variables that are not included in the public version of the data.

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[10] Commercial properties in the dataset that we received were selected based on a property category code that broadly describes the nature of the property, reflecting its highest and best use at the time of valuation. This may differ from the actual use of the property at the time. For example, there are multi-storey commercial properties in our dataset whose primary (but not necessarily sole) use is residential. Primary use is included as a control variable in all regressions.

Each record in the registry contains information on the physical location of the building and on the date and type of the earthquake-prone notice that was issued.[11] If the notice has been subsequently uplifted, the date and reason for the revision are also noted. To facilitate matching the seismic strength information to property sales, the WCC also added valuation reference information to each earthquake-prone building record for which a link to a valuation record could be established.

The earliest earthquake-prone notice in our dataset is from 2006. Over 80% of all notices that the council has issued occurred after the first Christchurch earthquake confirming that the Council put more emphasis on dealing with earthquake-prone buildings after that event.

For each commercial property sale, we establish if the property is related to a valuation reference that has been linked to an earthquake-prone building assessment. If multiple assessments are linked to a rating unit and key information in the assessments is not identical, we keep relevant information from each. In assigning earthquake-prone status to the rating unit in these cases, we use conservative assumptions. For example, if there is uncertainty around the date an earthquake-prone notice was issued due to conflicting dates from multiple assessments, we use the date of the latest notice to establish the unit's status.[12]

The number of sales in our final dataset is 832. Of these, 16 are for properties classified as earthquake-prone at the time of the sale. A total of 132 sales were for properties that would be declared earthquake-prone subsequent to sale. In the post-earthquake period there were 14 sales each of declared earthquake-prone buildings and buildings that would subsequently be declared as earthquake-prone. Thus we do not have large sales numbers with which to identify these effects; conversely, any significant effects that are found are in spite of these small numbers. The distribution of sales by earthquake-prone status, time period and location is shown in Table 1.

The average number of times each building in our dataset sold since 1998 is 1.54, with the majority of buildings having only a single sale associated with them. The small proportion of repeat sales means that we cannot control for unobservable building characteristics (for instance through the inclusion of building fixed effects). However, we can examine key observable characteristics related to building condition and to the likelihood of being earthquake-prone. Table 2 documents mean characteristics for our three classes of buildings (not earthquake-prone, earthquake-prone at time of sale, and earthquake-prone in future) according to CBD and suburban location (plus the Wellington total). The characteristics on which we focus are: year of construction, condition, and type of wall construction. Year of construction is based on the mid-point of the relevant construction decade. The condition variable is as listed by QVNZ, ranging from 1 (=poor) to 4 (= good). Wall construction is divided into brick and mixed versus other, with each of brick and mixed building material types being regarded as most likely to be earthquake-prone.

[11] There are three types of notices. A yellow notice is the standard earthquake-prone notice for general buildings. An orange notice is issued if the owner fails to comply with the conditions of the yellow notice, and a red notice is issued if the conditions set forth in the orange notice are not met. Due to the very low number of orange and red notices, we do not differentiate between various notice types.

[12] Our estimation results are not significantly affected by dropping sales that are linked to multiple assessments.

**Table 1** Time distribution of sales by earthquake-prone status and location

| EQ-prone status | Pre-EQ | Post-EQ | Total |
|---|---|---|---|
| **Not EQ-prone** | **555** | **129** | **684** |
| CBD | 303 | 69 | 372 |
| Suburbs | 252 | 60 | 312 |
| **EQ-prone at sale** | **2** | **14** | **16** |
| CBD | 1 | 10 | 11 |
| Suburbs | 1 | 4 | 5 |
| **EQ-prone future** | **118** | **14** | **132** |
| CBD | 68 | 6 | 74 |
| Suburbs | 50 | 8 | 58 |
| **Total** | **675** | **157** | **832** |

Pre-EQ and Post-EQ refer to pre- and post-first Christchurch earthquake (4 September 2010). Figures in bold apply to all of Wellington City; figures in normal font provide a break-down by location

**Table 2** Key building characteristics by earthquake-prone status and location

| Building characteristic | Wellington | CBD | Suburban |
|---|---|---|---|
| Mean year of construction | | | |
| Not EQ-prone | 1947 | 1941 | 1952 |
| EQ-prone at sale | 1924 | 1924 | 1925 |
| EQ-prone future | 1918 | 1913 | 1921 |
| Mean condition | | | |
| Not EQ-prone | 3.4 | 3.4 | 3.4 |
| EQ-prone at sale | 3.1 | 3.0 | 3.3 |
| EQ-prone future | 2.9 | 2.7 | 3.1 |
| % brick or mixed wall construction | | | |
| Not EQ-prone | 26 | 29 | 23 |
| EQ-prone at sale | 71 | 70 | 75 |
| EQ-prone future | 64 | 83 | 50 |

The table shows a clear distinction between not earthquake-prone buildings on the one hand versus (current and future) earthquake prone buildings on the other. Buildings that are not earthquake prone are younger, in better condition and much less likely to have brick or mixed wall construction than are buildings in the two earthquake-prone categories.

Within the two earthquake-prone categories, we see only small differences and to the extent these differences exist, they imply that current-declared earthquake-prone buildings are slightly younger, in slightly better condition, and (in the CBD) slightly less likely to have brick or mixed walls than are buildings subsequently declared as earthquake-prone. Thus, based on observables, the process of declaring buildings to be earthquake-prone does not appear to have started with 'worse' buildings before moving on to less affected buildings. Instead, it appears more likely that the timing of declarations was random, or at least not based on observable factors.

## Findings

### Sale Price

Our hedonic model of commercial building sale prices is estimated using OLS.[13] Full results are presented in the Appendix, with three separate estimates presented. The first includes all available observations within Wellington City while the second and third estimates subset on observations from the Wellington CBD and Wellington suburbs respectively in order to explore whether coefficients differ for CBD versus suburban properties. Discounts for CBD earthquake-prone buildings may differ from those for suburban buildings if costs of remediation are systematically different between the two areas and/or if rents for earthquake-prone buildings are affected more in one area than another. The equations include estimated coefficients both for properties that are declared earthquake-prone at time of sale and those that are declared earthquake-prone in future, and in each case include coefficients for the relevant variable interacted with the post-earthquake indicator.

Table 3 presents the post-earthquake (Post-EQ) marginal effects for the impact of the two earthquake-related variables (EQ-prone current; EQ-prone future) on the logarithm of sale price. These post-earthquake effects include the combined effect of the earthquake-prone variable and that variable interacted with the post-earthquake indicator. Three key results are apparent from our estimates.

First, buildings that have been declared earthquake-prone prior to the time of sale experience a statistically significant reduction in sale price following the Christchurch earthquakes. Second, this effect was more pronounced in the CBD than in suburban areas. Within the CBD, the implied sale price discount for being declared earthquake-prone is estimated at 44.6% ($=1-e^{-0.591}$), significant at the 1% level. An (insignificant) discount of 16.6% is estimated for suburban earthquake-prone properties while the estimated discount across all properties in Wellington is 25.5%. The latter two estimated discounts are estimated with less precision than the CBD estimate possibly because CBD commercial buildings are more homogeneous than are commercial buildings within the suburbs and across the entire city. We note that since remediation costs will vary widely across buildings, the estimated effects are average impacts, and actual discounts will vary around these estimated effects reflecting actual remediation costs.

A third key finding is that there is no estimated discount for buildings sold post-earthquake that were subsequently declared earthquake-prone. This is the case both for the CBD and the suburbs. Even though these buildings were subsequently declared to be earthquake-prone, implying that they were not at one third of the new building standard at the time of sale, they do not face the same discount as officially declared earthquake-prone buildings. The process of declaring a building to be earthquake-prone (especially in the CBD) therefore appears to crystallise the risk and/or costs associated with an earthquake-prone building in a way that a private engineering assessment at time of purchase does not.

[13] Since some buildings are sold more than once their residuals may not be independent, so we cluster standard errors on buildings.

**Table 3** Marginal effects for earthquake-prone indicators on sale prices

| Variable | Wellington | CBD | Suburbs |
|---|---|---|---|
| EQ-prone current*Post-EQ | −0.295* | −0.591*** | −0.181 |
| | (0.172) | (0.226) | (0.154) |
| EQ-prone future*Post-EQ | 0.122 | 0.008 | 0.113 |
| | (0.168) | (0.328) | (0.161) |
| Observations | 832 | 457 | 375 |

Marginal effects represent the change in the natural log of sale price for a discrete change in the value of the earthquake-prone indicator. Robust standard errors clustered on buildings are shown in parentheses. Asterisks indicate statistical significance (***$p < 0.01$, **$p < 0.05$, *$p < 0.10$). See the Appendix for the full set of results

Reflecting our discussion in section 2.2, we conjecture that this result may be driven by two possible factors. The first factor may be that some buyers are naïve in purchasing commercial buildings and face a winners curse in being the preferred buyer of a building that is not currently-declared earthquake-prone.[14] The second factor may be that engineering assessments differ in their assessment of earthquake-risk and buyers who purchase future-declared earthquake-prone buildings may instead believe that the prospective purchase lies above the minimum required standard. Even the second possibility implies some naivety on the part of buyers, however, since a fully rational investor should understand that there is a distribution around the central estimate of earthquake-code compliance. For instance, a building privately assessed as being at 40% of code must have a greater risk of being formally declared earthquake-prone than one at 100% of code. The results therefore imply the presence of at least some partially informed investors in the commercial property market.

## Sale Probability

We report the full estimated coefficients from sale probability logit models (using robust standard errors clustered on buildings) for Wellington, and for the CBD and suburbs, in the appendix. Most of the (non-earthquake) building attributes have non-significant parameter estimates; thus while these characteristics affect sale prices, they do not affect sale probability. Table 4 reports the post-earthquake marginal effects for the impact of the relevant earthquake-related variables on the probability of sale. We find a significant increase in the probability of sale of a declared earthquake-prone building, especially in the CBD, following the earthquakes. The estimated marginal effect (0.117 for Wellington city) is material in relation to the mean sale probability for the whole period of 0.069. This increase in sale probability is consistent with the hypotheses outlined in section 2.2.

In addition, we find a negative effect on sale probability following the earthquakes for buildings subsequently declared earthquake-prone, with the effect being greater in the CBD than in the suburbs. These buildings do not yet face the legal requirement for remediation, so the same imperative for forced sale does not exist. Instead, the result is consistent with caution regarding older (potentially earthquake-prone) buildings amongst some potential purchasers reducing the probability of sale for these buildings. Reticence to purchase older commercial buildings should also apply to currently-declared earthquake-prone buildings; yet this subset of

[14] More informed buyers would offer a lower price and so do not become the successful purchasers.

**Table 4** Marginal effects for earthquake-prone indicators on sale probabilities

| Variable | Wellington | CBD | Suburbs |
|---|---|---|---|
| EQ-prone current*Post-EQ | 0.117*** | 0.122*** | 0.075*** |
| | (0.021) | (0.022) | (0.020) |
| EQ-prone future*Post-EQ | −0.020** | −0.024** | −0.016 |
| | (0.008) | (0.010) | (0.012) |
| Mean sale probability | 0.0691 | 0.0693 | 0.0687 |
| Observations | 11,700 | 6336 | 5364 |

Marginal effects represent the change in sale probability for a discrete change in the value of the earthquake-prone indicator. For reference, the mean probability of sale is shown for each location category. Robust standard errors clustered on buildings are shown in parentheses. Asterisks indicate statistical significance (***$p < 0.01$, **$p < 0.05$, *$p < 0.10$). See the Appendix Table 5 for the full set of results

buildings increases in sale probability. The process of being officially declared earthquake-prone, which legally crystallises the need for remediation and which may highlight earthquake risks for tenants, therefore appears to be a catalyst that both decreases price and increases sale probability for earthquake-prone commercial buildings.

## Conclusions

There are few studies that examine impacts of a disaster on the property market outside of the area affected by the disaster and, as far as we can find, no studies of these impacts specifically for commercial buildings. This may well be because of the difficulty in compiling appropriate datasets to examine potentially disaster-prone commercial buildings. The assistance of public authorities in the compilation of our dataset has enabled us to conduct work in this area.

Our results indicate that the impacts on commercial buildings of a public policy that officially declares certain buildings to be earthquake-prone, can be marked. Following the earthquakes, we find that CBD buildings that are publicly declared as earthquake-prone suffer an estimated average price discount of 45%. This finding indicates a very significant loss in value for existing owners.

Our analysis indicates that the requirement to remediate the buildings within a specific time period raises the probability that existing owners of officially declared earthquake-prone buildings will sell their buildings. We conjecture that those who purchase the buildings may have lower funding costs (or preferential access to finance in a credit-constrained environment) relative to the existing owners. Existing owners may be forced sellers who have no option but to accept a highly discounted price on their buildings or they may simply be maximising their (discounted) return by selling to another party who is better placed to remediate the building.

From a policy perspective, an important result is that there is no estimated discount following the earthquakes for buildings that are subsequently declared to be earthquake-prone. These findings suggest that the action of declaring a building to be earthquake-prone has real impacts on the commercial property market. This effect may be due to the presence of naïve purchasers in the market and/or due to difficulties in judging the degree of earthquake code compliance even amongst professional engineers. We make no judgement as to whether the Council's declarations are accurate or warranted. Nevertheless, our results make clear that these declarations have a considerable impact on the commercial property market with an almost halving in price of commercial buildings that face a legally binding earthquake-prone declaration.

# Appendix

**Table 5** Full estimation results from the hedonic ordinary least squares and logit regressions

| | OLS hedonic sale price model | | | Logit sale probability model | | |
|---|---|---|---|---|---|---|
| Variable | Wellington | CBD | Suburbs | Wellington | CBD | Suburbs |
| Post-EQ | −0.0245 | −0.0644 | −0.392* | 0.901** | 0.846 | 0.943* |
| | (0.153) | (0.226) | (0.236) | (0.370) | (0.577) | (0.484) |
| EQ-prone current | 0.488*** | 0.296 | 0.487*** | −0.604* | −0.484 | −1.214** |
| | (0.166) | (0.219) | (0.140) | (0.349) | (0.397) | (0.501) |
| EQ-prone current*Post-EQ | −0.783*** | −0.886*** | −0.668*** | 2.082*** | 2.017*** | 2.314*** |
| | (0.245) | (0.326) | (0.204) | (0.325) | (0.365) | (0.641) |
| EQ-prone future | −0.00478 | −0.188* | 0.151* | 0.112 | 0.161* | 0.0512 |
| | (0.0723) | (0.103) | (0.0817) | (0.0684) | (0.0912) | (0.105) |
| EQ-prone future*Post-EQ | 0.127 | 0.197 | −0.0371 | −0.671** | −0.876** | −0.465 |
| | (0.179) | (0.332) | (0.174) | (0.300) | (0.423) | (0.428) |
| Year | | | | | | |
| 1999 | 0.157 | −0.114 | 0.178 | 1.338*** | 1.027** | 2.129*** |
| | (0.264) | (0.284) | (0.396) | (0.350) | (0.407) | (0.761) |
| 2000 | −0.0251 | −0.337 | 0.0443 | 1.662*** | 1.406*** | 2.367*** |
| | (0.267) | (0.294) | (0.359) | (0.341) | (0.392) | (0.753) |
| 2001 | 0.272 | 0.148 | 0.0840 | 1.917*** | 1.671*** | 2.609*** |
| | (0.248) | (0.258) | (0.357) | (0.336) | (0.385) | (0.746) |
| 2002 | 0.600** | 0.657*** | 0.357 | 1.721*** | 1.305*** | 2.652*** |
| | (0.243) | (0.250) | (0.363) | (0.324) | (0.364) | (0.745) |
| 2003 | 0.506** | 0.399 | 0.357 | 1.866*** | 1.406*** | 2.847*** |
| | (0.247) | (0.266) | (0.350) | (0.327) | (0.373) | (0.741) |
| 2004 | 0.726*** | 0.685** | 0.580 | 1.759*** | 1.439*** | 2.564*** |
| | (0.254) | (0.280) | (0.359) | (0.339) | (0.391) | (0.747) |
| 2005 | 0.832*** | 0.632** | 0.661* | 2.057*** | 1.773*** | 2.810*** |
| | (0.246) | (0.257) | (0.358) | (0.333) | (0.382) | (0.742) |
| 2006 | 0.930*** | 0.662** | 0.912*** | 1.996*** | 1.305*** | 3.194*** |
| | (0.258) | (0.301) | (0.351) | (0.330) | (0.385) | (0.736) |
| 2007 | 1.088*** | 1.039*** | 1.002*** | 1.759*** | 1.113*** | 2.917*** |
| | (0.244) | (0.249) | (0.363) | (0.334) | (0.391) | (0.740) |
| 2008 | 1.051*** | 0.960*** | 0.837** | 1.284*** | 0.933** | 2.129*** |
| | (0.256) | (0.277) | (0.356) | (0.352) | (0.412) | (0.761) |
| 2009 | 1.172*** | 1.188*** | 0.947*** | 1.068*** | 0.207 | 2.367*** |
| | (0.268) | (0.404) | (0.355) | (0.360) | (0.463) | (0.753) |
| 2010 | 0.883*** | 0.893*** | 0.801** | 0.917** | 0.251 | 2.090*** |
| | (0.256) | (0.278) | (0.358) | (0.383) | (0.488) | (0.777) |
| 2011 | 0.772** | 0.845** | 0.961** | 0.430 | 0.164 | 1.194 |
| | (0.313) | (0.364) | (0.448) | (0.511) | (0.696) | (0.921) |
| 2012 | 0.962*** | 0.817* | 1.401*** | 0.314 | −0.226 | 1.379 |
| | (0.310) | (0.420) | (0.425) | (0.522) | (0.734) | (0.910) |
| 2013 | 0.784** | 0.832** | 1.009** | 0.0387 | −0.367 | 0.974 |
| | (0.320) | (0.382) | (0.465) | (0.532) | (0.738) | (0.928) |
| 2014 | 0.791** | 0.841* | 1.073** | −0.000987 | −0.226 | 0.700 |
| | (0.323) | (0.437) | (0.432) | (0.536) | (0.735) | (0.942) |
| 2015 | 0.791** | 0.656 | 1.270** | −0.801 | −1.086 | −0.0143 |
| | (0.346) | (0.410) | (0.520) | (0.579) | (0.792) | (0.997) |
| Construction decade | | | | | | |
| 1880–1889 | 0.487*** | 0.595*** | | 0.0842 | 0.121 | |
| | (0.116) | (0.150) | | (0.282) | (0.284) | |
| 1890–1899 | −0.242* | −0.236 | 0.0141 | 0.0437 | 0.0729 | −0.181 |
| | (0.144) | (0.169) | (0.220) | (0.125) | (0.166) | (0.142) |
| 1910–1919 | 0.0791 | 0.171 | 0.0916 | −0.112 | −0.123 | −0.0846 |
| | (0.105) | (0.166) | (0.130) | (0.0900) | (0.146) | (0.108) |

**Table 5** (continued)

| | OLS hedonic sale price model | | | Logit sale probability model | | |
|---|---|---|---|---|---|---|
| 1920–1929 | 0.182 | | 0.223 | −0.521** | | −0.116 |
| | (0.263) | | (0.309) | (0.213) | | (0.157) |
| 1930–1939 | −0.218** | −0.293 | −0.200* | −0.207** | −0.272* | −0.161* |
| | (0.0984) | (0.200) | (0.106) | (0.0882) | (0.165) | (0.0974) |
| 1940–1949 | 0.0345 | −0.0568 | 0.0344 | −0.220** | −0.172 | −0.319*** |
| | (0.131) | (0.183) | (0.174) | (0.103) | (0.199) | (0.0904) |
| 1950–1959 | −0.373 | −0.616* | −0.199 | 0.0177 | −0.327 | 0.649*** |
| | (0.260) | (0.350) | (0.211) | (0.207) | (0.299) | (0.195) |
| 1950–1959 | −0.305** | −0.387* | −0.106 | −0.224** | −0.125 | −0.304*** |
| | (0.153) | (0.216) | (0.197) | (0.0955) | (0.200) | (0.0732) |
| 1960–1969 | −0.118 | 0.204 | −0.346** | −0.141 | −0.178 | −0.126 |
| | (0.133) | (0.181) | (0.155) | (0.0899) | (0.169) | (0.115) |
| 1970–1979 | 0.199* | 0.107 | 0.240** | −0.152* | −0.234 | −0.135 |
| | (0.118) | (0.221) | (0.120) | (0.0913) | (0.155) | (0.127) |
| 1980–1989 | 0.301*** | 0.226 | 0.396*** | −0.0932 | −0.125 | −0.0775 |
| | (0.112) | (0.180) | (0.138) | (0.0820) | (0.146) | (0.116) |
| 1990–1999 | 0.466*** | 0.260 | 0.610*** | −0.0952 | −0.0438 | −0.188 |
| | (0.173) | (0.305) | (0.186) | (0.110) | (0.178) | (0.154) |
| 2000–2009 | 0.383 | −0.0795 | 0.630* | −0.211 | −0.142 | −0.323* |
| | (0.241) | (0.286) | (0.367) | (0.205) | (0.397) | (0.171) |
| 2010–2019 | 1.077** | 1.215*** | 0.674 | −0.405*** | −0.432*** | −0.466*** |
| | (0.483) | (0.206) | (0.415) | (0.0870) | (0.144) | (0.125) |
| Indeterminate | 0.123 | −0.00269 | 0.116 | −0.132 | −0.133 | −0.138 |
| | (0.0965) | (0.150) | (0.108) | (0.0900) | (0.159) | (0.0962) |
| Land area | 0.820*** | 0.854* | −0.444 | 0.00390 | 0.114 | −0.182 |
| | (0.295) | (0.478) | (0.362) | (0.0953) | (0.265) | (0.144) |
| Location | | | | | | |
| CBD | 0.545*** | | | −0.00135 | | |
| | (0.0714) | | | (0.0486) | | |
| Location x Land area | | | | | | |
| CBD | −0.0523 | | | 0.103 | | |
| | (0.505) | | | (0.251) | | |
| Floor area | 0.0162*** | 0.0149*** | 0.0563*** | −0.00088* | −0.000704 | 0.00420 |
| | (0.00219) | (0.00222) | (0.00626) | (0.000460) | (0.000537) | (0.00339) |
| Land use | | | | | | |
| Transport | 1.865*** | 1.715*** | | −0.300*** | −0.276** | |
| | (0.272) | (0.399) | | (0.0847) | (0.108) | |
| Community services | −0.126 | −4.922*** | 0.0613 | −0.221*** | −0.591 | −0.181** |
| | (0.145) | (0.850) | (0.151) | (0.0564) | (0.481) | (0.0769) |
| Utility services | −1.059*** | −1.172*** | | | | |
| | (0.224) | (0.366) | | | | |
| Industrial | −0.338*** | −0.465*** | −0.0321 | 0.00956 | −0.113 | 0.160 |
| | (0.0840) | (0.132) | (0.105) | (0.0765) | (0.127) | (0.106) |
| Residential | 0.113 | −0.0661 | 0.326** | −0.0341 | −0.0765 | −0.00190 |
| | (0.0845) | (0.142) | (0.126) | (0.0677) | (0.131) | (0.0823) |
| Land use x Floor area | | | | | | |
| Transport | −0.842*** | −0.823** | | 0.0167 | −0.119 | |
| | (0.239) | (0.350) | | (0.102) | (0.145) | |
| Community services | 0.00888** | 0.758*** | −0.0156* | 0.000872 | 0.0534 | −0.00628 |
| | (0.00421) | (0.143) | (0.00830) | (0.00177) | (0.0801) | (0.00479) |
| Industrial | 0.00280 | 0.00144 | −0.0134 | −0.00276* | −0.000737 | −0.014*** |
| | (0.00435) | (0.00247) | (0.00858) | (0.00143) | (0.00170) | (0.00513) |
| Residential | 0.0122*** | 0.0124*** | −0.00241 | −0.000181 | −0.000799 | −0.00177 |
| | (0.00383) | (0.00344) | (0.0166) | (0.00257) | (0.00250) | (0.00512) |

**Table 5** (continued)

| | OLS hedonic sale price model | | | Logit sale probability model | | |
|---|---|---|---|---|---|---|
| Condition | | | | | | |
| Good | 0.0861 | −0.0183 | 0.106 | 0.0151 | −0.0287 | 0.0870 |
| | (0.0616) | (0.0836) | (0.0702) | (0.0479) | (0.0700) | (0.0679) |
| Fair | −0.0312 | 0.0413 | −0.205* | 0.0355 | 0.127 | −0.0332 |
| | (0.0981) | (0.124) | (0.112) | (0.0937) | (0.137) | (0.0929) |
| Poor | −0.373** | −0.622*** | −0.0186 | −0.105 | −0.146 | −0.206** |
| | (0.153) | (0.219) | (0.149) | (0.172) | (0.201) | (0.0935) |
| Mixed | −0.0996 | −0.393** | 0.117 | −0.0184 | −0.223** | 0.142 |
| | (0.135) | (0.191) | (0.140) | (0.0792) | (0.0912) | (0.112) |
| Wall construction | | | | | | |
| Aluminium | −0.833** | −0.636** | | −0.251 | −0.359 | |
| | (0.362) | (0.262) | | (0.267) | (0.434) | |
| Brick | −0.180* | −0.198 | −0.126 | −0.0781 | −0.0725 | −0.0919 |
| | (0.101) | (0.147) | (0.122) | (0.0713) | (0.114) | (0.0927) |
| Fibre cement, asbestos | −0.303 | −0.312 | −0.269 | −0.233** | −0.326*** | −0.196 |
| | (0.214) | (0.416) | (0.225) | (0.112) | (0.0995) | (0.130) |
| Glass | −0.605 | −0.428 | 1.439*** | 0.354 | 0.289 | 0.494*** |
| | (0.405) | (0.456) | (0.189) | (0.362) | (0.444) | (0.0928) |
| Iron | −0.143 | 0.477** | −0.207 | −0.207* | −0.292* | −0.203 |
| | (0.257) | (0.238) | (0.236) | (0.125) | (0.166) | (0.198) |
| Roughcast | −0.350 | | −0.346 | 0.198 | | 0.278 |
| | (0.243) | | (0.228) | (0.250) | | (0.241) |
| Stone | −0.239 | −0.111 | 0.502*** | −0.214** | −0.210 | −0.333*** |
| | (0.268) | (0.243) | (0.166) | (0.101) | (0.148) | (0.111) |
| Wood | −0.388*** | −0.716*** | −0.186 | −0.105 | −0.152 | −0.0572 |
| | (0.0958) | (0.145) | (0.116) | (0.0743) | (0.148) | (0.0849) |
| Mixed | −0.356*** | −0.267* | −0.367*** | −0.0413 | −0.0379 | −0.0174 |
| | (0.0900) | (0.141) | (0.104) | (0.0612) | (0.101) | (0.0747) |
| Roof construction | | | | | | |
| Aluminium | −0.0374 | 0.0756 | 0.0754 | 0.0457 | 0.0829 | 0.0375 |
| | (0.294) | (0.126) | (0.372) | (0.183) | (0.226) | (0.252) |
| Concrete | 0.340*** | 0.344*** | −0.0819 | −0.0499 | −0.0598 | 0.0304 |
| | (0.115) | (0.124) | (0.230) | (0.0627) | (0.0710) | (0.176) |
| Fibre cement, asbestos | 0.422** | 0.0870 | 0.588** | 0.0588 | −0.00744 | 0.0755 |
| | (0.175) | (0.169) | (0.299) | (0.117) | (0.159) | (0.159) |
| Glass | 1.785*** | | | 0.110 | | |
| | (0.430) | | | (0.369) | | |
| Fabric, bitumen, rubber | 0.178 | 0.180 | −0.500 | −0.106 | −0.102 | −0.223* |
| | (0.194) | (0.184) | (0.347) | (0.0828) | (0.110) | (0.115) |
| Tiles | −0.0143 | −0.596 | 0.000397 | 0.0455 | 0.104 | −0.00175 |
| | (0.186) | (0.485) | (0.145) | (0.103) | (0.208) | (0.117) |
| Mixed | 0.221*** | 0.223* | 0.267*** | −0.0751 | −0.0244 | −0.133 |
| | (0.0820) | (0.130) | (0.0999) | (0.0724) | (0.101) | (0.0842) |
| Constant | 12.78*** | 13.68*** | 12.63*** | −3.884*** | −3.428*** | −4.871*** |
| | (0.270) | (0.306) | (0.369) | (0.306) | (0.349) | (0.716) |
| Observations | 832 | 457 | 375 | 11,700 | 6336 | 5364 |
| Adjusted/Pseudo R-squared | 0.753 | 0.767 | 0.698 | 0.037 | 0.041 | 0.045 |

Robust standard errors clustered on buildings are shown in parentheses. Asterisks indicate statistical significance (***$p < 0.01$, **$p < 0.05$, *$p < 0.10$). Observations in the logit estimation represent building-year combinations. Unlike the main text, this table reports estimated coefficients from the logit model, rather than marginal effects. Adjusted and pseudo R-squared is reported for the hedonic and logit models, respectively

Omitted (base) categories are: Year (1998), Construction decade (1900–1909), Location (Suburban), Land use (Commercial), Condition (Average), Wall construction (Concrete), Roof construction (Iron)

## References


Bin O, Kruse J (2006) Real estate market response to coastal flood hazards. Nat Hazard Rev 7(4):137–144

Bin O, Landry CE (2013) Changes in implicit flood risk premiums: empirical evidence from the housing market. J Environ Econ Manag 65(3):361–376

Bin O, Polasky S (2004) Effects of flood hazards on property values: evidence before and after hurricane Floyd. Land Econ 80:490–500

Bléhaut M (2015) Risque industriel, prix des logements et ségrégation résidentielle. Rev Française D'écon 30: 137–153

Brookie R (2012) Governing the recovery from the Canterbury earthquakes 2010-11: the debate over institutional design. Working paper 12/01, Institute for Governance and Policy Studies, Victoria University of Wellington

Diewert W, Shimizu C (2017) Alternative approaches to commercial property price indexes for Tokyo. Rev Income Wealth 63(3):492–519

Diewert W, Fox K, Shimizu C (2015) Commercial property price indexes and the system of national accounts. J Econ Surv 30(5):913–943

Filippova O, Rehm M (2017) Office market response to earthquake risk in New Zealand. J Prop Invest Financ 35(1):44–57

Gallagher J (2014) Learning about an infrequent event: evidence from flood insurance take-up in the United States. Am Econ J: Appl Econ 6(3):206–233

Grimes A, Hyland S (2015) Housing markets and the global financial crisis: the complex dynamics of a credit shock. Contemp Econ Policy 33(2):315–333

Hill R (2013) Hedonic price indexes for residential housing: a survey, evaluation and taxonomy. J Econ Surv 27(5):879–914

LINZ. 2010. Rating valuations rules 2008. Office of the Valuer-General, Land Information New Zealand, Wellington LINZS30300 Version date: 1 October 2010

Meyer R, Kunreuther H (2017) The Ostrich Paradox: Why we Underprepare for Disasters. Wharton Digital Press, Philadelphia

Murdoch JC, Singh H, Thayer M (1993) The impact of natural hazards on housing values: the Loma Prieta earthquake. Real Estate Econ 21(2):167–184

Naoi M, Seko M, Sumita K (2009) Earthquake risk and housing prices in Japan: evidence before and after massive earthquakes. Reg Sci Urban Econ 39(6):658–669

Parker M, Steenkamp D (2012) The economic impact of the Canterbury earthquakes. Reserv Bank N Z Bull 75(3):13–25

Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. J Polit Econ 82(1):34–55

Samarasinghe O, Sharp BMH (2010) Flood prone risk and amenity values: a spatial hedonic analysis. Aust J Agric Resour Econ 54(4):457–475

Storey B, Noy I (2017) Insuring property under climate change. Policy Q 13(4):68–74

Thomas GC, Hosler MD, Cody SB (2013) Quantifying seismic strengthening in Wellington’s commercial building stock. New Zealand Society for Earthquake Engineering (NZSEE) Annual Technical Conference 2013

Thornton AW (2010) Twenty-five years of strengthening wellington. Paper 26, new Zealand Society for Earthquake Engineering Conference

Timar L, Grimes A, Fabling R (2014) That sinking feeling: the changing price of disaster risk following an earthquake. Motu working paper 14-13, wellington: Motu

Treasury (2013) Half year economic and fiscal update 2013. The New Zealand Treasury: Wellington.

WCC (2009) Earthquake-prone buildings policy. Wellington City Council, Wellington NZ. Available online at http://wellington.govt.nz/~/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/earthquakepronebldgs/files/earthquake.pdf. Accessed 4 Sept 2015

WCC (2015) Earthquake prone buildings - Wellington City Council guide. Wellington City Council, Wellington NZ. Available online at http://wellington.govt.nz/~/media/services/rates-and-property/earthquake-prone-buildings/files/eq-prone-buildings-guide.pdf. Accessed 4 Sept 2015