Before a Fall:
Impacts of Earthquake Regulation and Building Codes on the Commercial Building Market

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Abstract
We test whether a major earthquake in one city (Christchurch, New Zealand) affects the prices of earthquake-prone commercial buildings in a city (Wellington) that was unaffected by the disaster. In particular, we test whether the official public declaration of a building as being earthquake-prone (with a corresponding requirement to remediate the building to minimum earthquake code requirements) has an effect on price over and above that experienced by similarly earthquake-prone (but not yet declared) buildings. We distinguish the latter by isolating sales of those buildings that are subsequently declared to be earthquake-prone. We find that in the CBD, the price discount that accompanies an official earthquake-prone declaration averages 45% whereas there is no observable discount on buildings that are subsequently declared earthquake-prone. Consistent with our theoretical model that anticipates forced sale of some officially declared earthquake-prone buildings, the probability of sale of officially declared earthquake-prone buildings rose markedly after the Christchurch earthquakes. Our results therefore show that officially declared earthquake-prone status has a considerable impact on the commercial property market that is separate from the effects of being earthquake-prone but where the building has not (yet) officially received that status.

JEL codes
Q54, R33, R38

Keywords
Earthquake-prone buildings, commercial property prices, forced property sale

Contents

1. Introduction

We examine the effects of the devastating Christchurch, New Zealand earthquakes on commercial building prices in an earthquake-prone (but directly unaffected) city, 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 price impacts on commercial buildings, following an earthquake, 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 two years and approximately 16,000 properties were severely damaged. The Treasury (2013) estimated that total investment associated with the city's rebuild was expected to 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

[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).

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, this re-evaluation is hypothesised to have impacted especially 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 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 first step in understanding the role and effects of public policy intervention.

1.1. 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 by then. 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.[3] 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.

[3] The legislation does not apply to small single-storey residential dwellings.

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 six 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 also 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.

Since the devastating earthquakes that struck Canterbury, 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).

1.2. Hypotheses

We hypothesise that 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. These hypotheses reflect both the costs that have to be incurred to upgrade the building to at least one-third of current building standards and the reduced rent that may be received as tenants factor in the extra risk of locating within a more dangerous building.[4]

[4] 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.

Given this overarching hypothesis, we test for several specific effects. First, we test whether the discount for earthquake-prone buildings increased following the Christchurch earthquakes. Research into housing markets in the Wellington Region showed an immediate drop in prices of vulnerable houses following the first Christchurch earthquake (Timar et al., 2014), 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 but were not declared earthquake-prone at the time of sale. We again differentiate this effect between pre- and post-Christchurch earthquake. Rational buyers should take account of the likely future earthquake-prone status of buildings when purchasing a commercial building, so we expect little or no difference in discount between currently declared earthquake-prone buildings and future-declared earthquake-prone buildings. This is expected especially to be the case following the Christchurch earthquakes when awareness of earthquake risks was heightened.

One reason why future-declared earthquake-prone buildings may sell at a lesser discount than currently declared earthquake-prone buildings is if it is 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. 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 degree of code compliance.

A separate set of hypotheses that we test concerns the probability of sale of buildings currently declared and declared in future as earthquake-prone. 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). However, our situation differs in that owners of earthquake-prone buildings 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 conceivably increase or decrease the probability of sale of an earthquake-prone building. Owners who cannot finance the required reconstruction may become forced sellers and this may increase the probability of sale. Conversely, prospective buyers may be deterred from purchasing an earthquake-prone building and this may reduce the probability of sale.

Based on a model that we outline below, we hypothesise that being declared earthquake-prone (especially after a major earthquake when enforcement of the legal requirement to upgrade the building promptly may have become more binding) will increase the probability of sale of a building with current earthquake-prone status.

The model assumes two possible owners for a building: person A and person B. At the margin, person A can finance reconstruction at a lower relative cost (e.g., through using internally-generated funds) with opportunity cost r^A. Person B must access higher cost (e.g., market-sourced external funds) at rate r^B, where $r^B > r^A$.[5] Let the value of the building (prior to being declared earthquake-prone) be equal to the present discounted value of future net rents, R (using the externally-sourced market interest rate, r^B), and let the cost of required reconstruction following an earthquake-prone listing be C. In the absence of a current or expected future earthquake-prone notice, each person will bid R for the building reflecting the market return. However, once declared earthquake-prone, person B will value the building at R-C(1+ r^B) while person A will value it at R-C(1+ r^A) > R-C(1+ r^B). If A already owns the building, they will retain ownership following receipt of an earthquake-prone notice, but if B owns the building there is a surplus of C(r^B- r^A) to be shared by B selling the building to A. Thus (in the absence of any information as to the owners' financial situations) the observed probability of sale should increase for a building that is declared earthquake-prone.

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. If anything, the probability of sale may decline (especially after the earthquake) if some 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 issue since the properties that are sold are not a random sample of all commercial properties. One way to accommodate 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

[5] Alternatively, in the presence of credit constraints, person A may have access to the funds necessary for remediation whereas person B may not have similar access. 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.

price equation and the sale probability equation separately and use the results from the latter to aid our interpretation of the results from the sale price equation.

We discuss our modelling approach in section 2, and discuss the data in the subsequent section. Section 4 presents our results for both the sale price equation and the sale probability equation. Brief conclusions are contained in section 5.

2. Modelling approach

We estimate separate hedonic sale price and probability of sale models, recognising that we have insufficient data to perform a Heckman correction. Diewert et al. (2015) note that the hedonic regression approach, while data intensive, is probably the most efficient method for using available market sales data to decompose prices into the value of land and the values for each structural attribute of properties. Diewert and Shimizu (2014) apply the hedonic regression approach to appraised values of Tokyo office buildings, but data requirements mean that there are very few existing studies that apply the approach to the sale prices of commercial buildings. As well as our particular application to the effects of a disaster on commercial property prices, our access to comprehensive building attributes data therefore enables us to break new ground in applying the hedonic regression methodology to commercial buildings.

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

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

where $Price_i^t$ is the sale price of building *i* sold in year *t*, α is a constant term, μ^t is a year dummy to reflect macroeconomic conditions (including the average price level) at time of sale, $\boldsymbol{X_i}$ 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, $\boldsymbol{\gamma}$), and ε_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,[6] wall construction and roof construction. The results table in the appendix details the exact 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),[7] an indicator of whether the building had been

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

[7] 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

declared earthquake-prone at time of sale, an indicator of whether the building was subsequently declared earthquake-prone (but was not declared prone at time of sale), plus each of these last two variables interacted with the post-earthquake indicator. The interaction terms test whether the discount applied to (current or future) earthquake-prone buildings changed following the first Christchurch earthquake.

Inclusion of the variable indicating that a building is found to be earthquake-prone at a future date helps to address concerns of endogeneity around building assessments. The City Council prioritises assessments by importance, and buildings considered more important (and hence assessed earlier) could plausibly be more desirable in ways we may not be able control for. Therefore, the set of buildings declared to be earthquake-prone earlier during the course of assessments may have a price premium associated with them, which could affect the estimates.

For our empirical strategy regarding future-declared earthquake-prone buildings to work, it is necessary that building assessments have 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) indicates that, in theory, all potentially earthquake-prone buildings have 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 some 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 variables, so we confine our discussion to these estimated effects. Consideration of the other hedonic estimates (which are provided in the results table in the appendix) show them all to have sensible properties, providing a sound basis for inferences of the earthquake effects that are our focus.

In accordance with our hypotheses, we expect that being earthquake-prone at time of sale will have a negative effect on sale price as will being subsequently declared as earthquake-prone,

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was sold between the two earthquakes, and the impacts of changing the definition of this indicator variable were negligible.

where the latter discount reflects an expectations effect. We also anticipate that the two post-earthquake interaction variables will have an (additional) negative effect on price as salience of earthquake-related issues rises following the first Christchurch earthquake. We have no priors for the post-earthquake indicator itself (which has no economic significance given the presence of the year dummies) since it pertains to all buildings and will reflect macroeconomic changes within 2010 as well as any earthquake-related effects that are common to all commercial buildings.

Our probability of sale equation has exactly the same form as equation (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 1.2, we expect that being earthquake-prone at time of sale will have a positive effect on sales probability whereas being declared earthquake-prone in future may be associated with a negative impact on sale probability.

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. However, unless they are systematically related to our variables of interest, their effect will be to decrease precision of the estimates rather than to cause bias in them.

3. 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 recorded in a way that can be accurately 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 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.[8] The time distribution of sales is uneven with

[8] 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

nearly 90% of sales in the raw dataset taking place in the last 18 years. Due to the patchiness of early data, 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 (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 we strongly suspect that the sale did not involve a building – most often, these seem to be 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.

The ability to identify individual structures is not the main priority for valuation. For example, buildings within the same complex may belong to the same rating unit (that is, they may be valued as one). In some cases, this makes it difficult to link seismic strength information to the sales data and this could be a source of noise in our data.

Wellington City Council provided us with 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), as well as having access to some additional variables that are not included in the public version of the data.

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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.[9] 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.[10]

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 Canterbury 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.[11]

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, and all but two of the 16 sales took place in the post-earthquake period. Because there were only two sales of declared earthquake-prone buildings prior to the first Christchurch earthquake, we place little reliance in our subsequent discussion on the effect of earthquake-prone building status prior to the first earthquake. 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 will be in spite of these small numbers. The distribution of sales by earthquake-prone status, time period and location is shown in Table 1.

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[9] 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.

[10] A one-to-one match between the datasets is not always possible. A valuation property may straddle multiple LINZ lots, and, vice versa, a survey property can have multiple valuation assessments to reflect different tenancies.

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

Table 1. Time distribution of sales by building 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**

Notes: 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.

The average number of times each building in our dataset has been sold since 1998 is 1.54, with the majority of buildings having only a single sale associated with them.[12]

4. Findings

4.1. Sale Price

Our hedonic model of commercial building sale prices is estimated using OLS with standard errors clustered on buildings. 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 2 presents pre- and post-earthquake marginal effects for the impact of the relevant earthquake-related variables on the logarithm of the sale price. The post-earthquake effects

[12] Because a rating unit may not identify a structure accurately, we have used strict constraints in calculating these repeat sales statistics: in addition to the valuation reference, the certificate of title and key characteristics must also match for two sales to be associated to the same building. For example, an upgraded or altered building may not meet this definition, so sales prior to and after the upgrade could be counted as sales of a different building. We use the same conditions to identify repeated observations of the same building for the purpose of clustering standard errors in the hedonic regression and to identify sale outcomes by building by year for the logit estimation.

reported in Table 2 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.

Table 2. Marginal effects for the earthquake-prone indicators on commercial building sale prices

Variable / period	Wellington	CBD only	Suburbs only
EQ-prone at sale			
Pre-EQ	0.488***	0.296	0.487***
	(0.166)	(0.219)	(0.140)
Post-EQ	-0.295*	-0.591***	-0.181
	(0.172)	(0.226)	(0.154)
EQ-prone future			
Pre-EQ	-0.005	-0.188*	0.151*
	(0.072)	(0.103)	(0.082)
Post-EQ	0.122	0.008	0.113
	(0.168)	(0.328)	(0.161)
Observations	832	457	375

Notes: 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).

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 (on which we have no data).

A third key finding is that for the full Wellington estimates, there is no estimated discount for buildings declared in future to be earthquake-prone that were sold prior to the earthquakes. A slight discount and a slight premium are observed in the CBD and suburbs respectively but neither of these is significant at the 5% level. More importantly, there is no estimated discount for buildings sold post-earthquake that will subsequently be declared earthquake-prone. This is the case both for the CBD and the suburbs. Even though these buildings are not at or above one third of the new building standard at the time of the sale and will, therefore, subsequently be declared earthquake-prone, 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 (including foregone rental costs) associated with an earthquake-prone building in a way that a private engineering assessment at time of purchase does not.

This is a surprising result that we conjecture 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 has no current legal status of being earthquake-prone.[13] The second factor may be that engineering assessments differ in their assessment of earthquake-risk and buyers who purchase future-declared earthquake-prone buildings 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 so that, 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.

4.2. Sale Probability

We report the full estimated coefficients from sale probability logit models (using robust standard errors clustered on buildings) for Wellington City, 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 tend not to affect sale probability.

Table 3 reports the pre- and post-earthquake marginal effects for the impact of the relevant earthquake-related variables on the probability of sale. We find no significant effect of future-declared earthquake-prone status on sale probability in Wellington City[14] prior to the Christchurch earthquakes. There is an estimated small reduction in sale probability for currently-declared earthquake-prone buildings prior to the earthquakes but again this is identified off only two sales so we place no emphasis on this result.

Following the earthquakes, we find a significant increase in the probability of sale of a declared earthquake-prone building, especially in the CBD. The estimated marginal effect (0.117 for Wellington city) is material in relation to the mean sale probability for the whole period of

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

[14] We also find no significant effect for the suburbs; in the CBD there is a small positive effect but that is significant only at the 10% level.

0.069. This increase in sale probability is consistent with the theoretical model discussed in section 1.2.

We find a slight negative effect on sale probability following the earthquakes on buildings subsequently declared as earthquake-prone, with the effect being more pronounced in the CBD than in the suburbs. These buildings do not yet face the legal requirement for remediation and so the same imperative for forced sale does not exist. Instead, caution regarding older (potentially earthquake-prone) buildings amongst some potential purchasers may reduce the probability of sale for these buildings. The process of being declared earthquake-prone, which legally crystallises the need for (costly) remediation, and which may also highlight earthquake risks for tenants, therefore appears to be a catalyst that both decreases price and increases sale probability for earthquake-prone commercial buildings.

Table 3. Marginal effects for the earthquake-prone indicators on commercial building sale probabilities

Variable / period	Wellington	CBD only	Suburbs only
EQ-prone at sale			
Pre-EQ	-0.034**	-0.029	-0.054***
	(0.015)	(0.019)	(0.013)
Post-EQ	0.117***	0.122***	0.075***
	(0.021)	(0.022)	(0.020)
EQ-prone future			
Pre-EQ	0.008	0.012*	0.004
	(0.005)	(0.007)	(0.008)
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	6,336	5,364

Notes: 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).

5. 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 initiate work in this area.

Our results indicate that the impacts on commercial buildings of being earthquake-prone, when combined with an explicit public policy that officially declares certain buildings to be earthquake-prone, can be marked. 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 theoretical model and empirical estimates indicate 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, the most surprising result in our study is that there is no estimated discount following the Christchurch 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 the effect being an almost halving in price of commercial buildings that face a legally binding earthquake-prone declaration.

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Appendix

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

	Hedonic model			Logit model		
Variable	Wellington	CBD	Suburbs	Wellington	CBD	Suburbs
Year						
1998	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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 time						
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)
1900-1909	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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)

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)		
Suburban	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Location x Land area						
CBD	-0.0523			0.103		
	(0.505)			(0.251)		
Suburban	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Floor area	0.0162***	0.0149***	0.0563***	-0.000879*	-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)
Commercial	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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)
Utility services	0	0				
	(.)	(.)				
Industrial	0.00280	0.00144	-0.0134	-0.00276*	-0.000737	-0.0135***
	(0.00435)	(0.00247)	(0.00858)	(0.00143)	(0.00170)	(0.00513)
Commercial	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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)
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)
Average	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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)
Concrete	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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	0.110		0
	(0.430)		(.)	(0.369)		(.)
Iron	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
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)
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 at sale	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 at sale x 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 x 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)
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	6,336	5,364
Adjusted/Pseudo R-squared	0.753	0.767	0.698	0.037	0.041	0.045

Notes: 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.

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