Regressivity in Public Natural Hazard Insurance: A Quantitative Analysis of the New Zealand Case

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Abstract: Natural hazard insurance is almost always provided by the public sector (directly, or indirectly through public-private partnerships). Given this dominant role of the public sector in hazard insurance, and the importance of shocks in economic dynamics, it is surprising that equity issues have not faced more scrutiny with respect to the design of hazard insurance. The nature of the regressivity we quantify has not been previously identified. We provide a detailed quantification of the degree of regressivity of the New Zealand earthquake insurance program – a system that was designed with an egalitarian purpose. We measure this regressivity as it manifested in the half a million insurance claims that resulted from the Canterbury earthquakes of 2011. We suggest how this regressivity can be remedied with modifications to the programs' structure, and point to how other insurance schemes internationally are likely to also be regressive.

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1. Introduction

Private natural hazard insurance markets seldom succeed in providing widespread coverage (Kunreuther and Pauly, 2009; Noy, Cuong, and Kusuma, 2017).[1] There are multiple examples of failed attempts to provide financial natural hazard risk transfer (insurance) through private markets, flood and earthquake insurance in the United States being two prominent cases. In fact, no country has a private market for flood insurance that provides affordable and accessible cover for high-risk households without some form of government involvement (ABI 2011).

A good insurance system incentivizes risk reduction and enables the insured party to take on beneficial and profitable business risks and invest ex ante; ex post, it allows the insured party to evade at least some of the financial loss, avoid destitution, and recover more quickly and more fully. O'Neill & O'Neill (2012) further argue that insurance should guarantee the security of required basic goods, according to social justice criteria, independently of the risks involved and the risk-taking by individuals — housing being a prime example for a 'basic good'.

From a communitarian rather than an individualist perspective, the inability of some households to rebuild their pre-disaster lives inflicts additional harm on the rest of the community. But, even from an individualist perspective, if there is no provision of natural hazard insurance by the private market, governments find a political-electoral rationale for intervention to facilitate insurance coverage for all. Governments can choose to pursue this aim by either insuring directly or subsidizing the private insurance sector, and have chosen

[1] Natural hazard insurance is also known as catastrophe insurance, disaster insurance, or natural disaster insurance, depending on the context. We use natural hazard insurance for specificity.

to do so in many countries.[2] Given the complexity of insuring extreme risks, private-sector insurers and governments tend to cooperate in public-private-partnership (PPP) schemes.[3]

Most disaster economists also argue that insurance premiums should be risk based (e.g., Bin, Bishop & Kousky, 2010 and Kunreuther, 2015). Risk-based insurance premiums signal to residents and businesses the hazards they face and enable insurers to lower premiums for properties for which steps have been taken to reduce risk. Risk-based premiums, however, do raise equity concerns, and there is some recognition that a fully risk-sensitive insurance regime may be socially or politically unacceptable if it imposes very high costs on some groups (Houston et al., 2011).[4]

Given the dominant role of the public sector in the provision of natural hazard insurance, and the evident concern worldwide about growing income and wealth inequality, it is surprising that equity issues have not faced more scrutiny with respect to publicly provided natural hazard insurance. For example, this aspect of the recently launched UK government FloodRe program has received almost no attention, in spite of the potentially very regressive structure of that program.

In this paper, we provide—possibly for the first time—a detailed quantification of the degree of regressivity of a public natural hazard insurance scheme and the channel through which it is generated. We chose to focus on the New Zealand (NZ) earthquake insurance scheme for four main reasons: (1) The availability of claims records after a large event (the

[2] Belgium, France, Japan, New Zealand, Spain, Switzerland, Turkey, UK, and the USA to name only a few.
[3] Paudel (2012) provides nine recommendations for designing such PPP schemes. His recommendations include: mandatory participation; adequate enforcement to ensure compliance; public responsibility for the extreme risk (the catastrophic end) of the insured risk, private sector administering of policies; public provision of subsidies through, for example, tax exemptions; public investment in risk mitigation; a (publicly provided) detailed assessment and mapping of risk; and the provision of financial incentives for policyholders to take risk mitigation measures.
[4] Kunreuther (2015) suggests that to address issues of equity and fairness, homeowners who cannot afford insurance could be given vouchers tied to loans for investing in loss reduction measures, but this kind of voucher program is yet to be implemented anywhere.

series of Canterbury earthquakes in 2010–2011 that led to a very large number of claims); (2) The well-established success of this program in achieving wide-spread coverage – the Canterbury earthquakes were the most insured large-scale series of events ever[5]; (3) The egalitarian aim of this scheme (all dwellings pay identical premiums and receive the same amount of cover); and (4) The comparatively egalitarian distributional policy of past and present NZ governments.

In spite of both (3) and (4), we find that the current NZ scheme is strongly regressive, and we report on the exact extent of this regressivity as it manifested in the half a million insurance claims that resulted from the Canterbury earthquakes.

2. Regressivity and Natural hazard insurance

Fairness has long been discussed in the evaluation of taxation (e.g., Simons, 1938; Goode, 1980). Economists have generally recognised two principal concepts of fair taxation: benefit, and the ability to pay. From a benefit perspective, taxes should be levied such that benefits received by the payers are proportional to their tax burden. Under this concept of fairness, there is little scope for redistribution. An example is motor fuel excise tax, which is used to pay for roadway construction and maintenance. The ability to pay principle focuses only on the cost side, while ignoring the distribution of benefits. It views taxation as imposing a cost that should be allocated in such a way that it taxes those with equal ability to pay equally

[5] The three highest cost earthquakes in the Canterbury sequence are among the top 10 costliest earthquakes for 1980–2015 (by insured losses). Relative to damages, these events were at least twice as well insured as any of the others on the list (MunichRe, 2016).

(horizontal equity), and imposes a greater burden on those with greater ability to pay (vertical equity).[6]

The concept of regressivity was originally applied to income tax systems. As defined in Kakwani (1977), if T(x) is the tax paid by an individual with income x, the tax system is proportional when the elasticity of T with respect to x is equal to one for all x, the tax system is progressive when the elasticity exceeds one, and regressive when the elasticity is less than one. This is equivalent to saying that a tax system is progressive, proportional, and regressive when the marginal tax rate is greater, equal, and less than the average tax rate, respectively.[7]

Musgrave and Thin (1948) created a more universal measure of progressivity by comparing the inequality of income distributions pre-tax and post-tax. A progressive tax system will then create a decrease in income inequality, while regressive tax rates will be reflected by increases in income inequality. The authors were able to conclude that if the Gini index is used to measure inequality, the ratio of the Gini indices of the before-tax and after-tax incomes provides a single measure of tax progressivity.[8]

Previous work has looked at the regressivity of explicit tax schemes; examples include "sin" taxes[9] and carbon taxes.[10] This type of measurement of progressivity has also been used to study implicit taxes and subsidies. For example, Davis and Knittel (2016) investigate whether

[6] Ability to pay is generally measured by annual income. There is no agreed upon standard to determine what vertical differentiation in tax liabilities is most fair (Joint Committee on Taxation, 2015).
[7] Slitor (1948) used this type of definition to propose a measure of progression: dt(x)/ dx = [m(x) -t(X)]/x; where t(x) is the average tax rate at the income level x and m(x) is the marginal tax rate at that level of income.
[8] Kakwani (1977), however, pointed out that by doubling the tax rates at all income levels, the tax progressivity would mechanically increase when using the Musgrave-Thin ratio. This is problematic because progressivity (or regressivity) is supposed to measure the deviation of a tax system from proportionality. Kakwani proposes to use the Gini index only to measure the distributional effects of taxation, and presents an alternative measure using the Lorenz Curve to create a measure that accounts for both the distributional and proportional elements of a tax system.
[9] Poterba (1991a), Lyon & Schwab (1991), Bento et al. (2012), and Borren & Sutton (1992).
[10] Wier et al (2005), and Poterba (1991b).

fuel efficiency standards are regressive, and Johnson (2006) looks at public spending on higher education.

While the potential distributional aspect of public natural hazard insurance has been noted in the literature, the practical implications in terms of benefits (expected payment of claims) relative to costs (premiums paid) have not previously been quantified.

Ben-Shahar and Logue (2015) examine Florida's state-owned Citizens' Property Insurance Corporation ("Citizens") and its coverage for wind-damage (hurricanes). Their work relies on Citizens' own calculations of the actual risk it takes on when providing insurance, and on the premiums it charges. They find that the higher subsidies are provided for areas incurring more risk, and that these areas are generally (statistically) wealthier, most likely because they are located closer to the coast. A second paper that investigates a similar program, by Bin, Bishop, and Kousky (2012), studies the U.S. National Flood Insurance Program (NFIP). It focuses on the departure from the proportionality measure of progressivity. A progressive departure from proportionality requires that every premium decile be no larger than the corresponding income decile. The authors show that the departure-from-proportionality index is not significantly different from zero for premiums, implying they are proportional to income. They consider premiums and payments separately, and note that neither effect is extreme and that these effects are smoothed over time.

Howard (2016) examines the net social benefits of the NFIP, using data on premiums, claims, policies, and grants from 1996–2010. In his more comprehensive analysis (than Bin et al., 2012) he finds that this system is "moderately regressive." According to these three analyses of the natural hazard insurance in the U.S., it is plausible that the distributional aspect arises solely from the differentiated exposure of wealthier households, due to their location on the coasts and the focus on hurricane damage, as many of the NFIP claims arise from storm-generated wave surges. In many cases, and in most countries, however, it is generally the poorer households that are more exposed (Karim and Noy, 2016).

Surminski (2016) and Davey (2015) discuss various distributional aspects of FloodRe, the UK's new flood reinsurance programme that is designed to maintain affordably priced flood insurance. Both papers identify several ways in which FloodRe may have distributional consequences, but do not quantify them. O'Neill & O'Neill (2012) discuss flood insurance in the UK (before the launch of FloodRe) and argue for a solidarity-based scheme on fairness grounds, acknowledging that risk based premiums would unfairly penalise households who could not reasonably be found to have chosen to live in flood prone areas of their own will. They note that "choice is voluntary only if it can be reasonably foreseen and the agents have real and acceptable alternatives to it." This statement raises interesting equity questions, as it is likely that those households facing higher risks are wealthier, in which case the fairness principle they advocate may lead to the insurance transferring risk from rich to poor households, and thereby the poor subsidising the rich.[11]

Here, we quantify the distributional effect of public natural hazard insurance in a NZ case, and identify the unfortunate regressivity of one of the theoretically most equitably designed public natural hazard insurance systems globally. It is easy to argue that many of the other public natural hazard insurance systems established globally (see Table 1) are likely to be at least as regressive. The next section describes the data we use for our quantitative analysis.

[11] The question of fairness becomes even more complicated if the hazard being insured is climate-related and its frequency or intensity is changing because of climate change. In this case, insurance systems provide a certain degree of collective protection with some distributional consequences, but the insured event was outcome of actions for which there is an uneven, shared responsibility. For flooding, it is the outcome of actions for which those who are most vulnerable often are at least hypothetically the least responsible. There is a double injustice if those with low incomes who are least responsible for anthropogenic global warming are faced with the largest burdens of damages (Thumim et al., 2011, Lindley et al., 2011).

Section 3 explains the methodology, in Section 4 we explain our results, and Section 5 concludes.

3. Data

In NZ, public natural hazard insurance is provided to residential homeowners by the Earthquake Commission (EQC). In order to access this insurance, homeowners need only have private fire insurance (which over 90% do). The public EQC premiums are collected through private fire insurers, and are identical for building cover of all dwellings insured for more than NZ$ 100,000 (as almost all are).

To fully appreciate the role EQC plays, we must consider how it developed. In 1906 San Francisco was hit by a devastating earthquake, hitting German insurers especially hard. In the wake of this event, much of the global insurance industry responded by excluding earthquake and related fire damage from their policies (Henderson, 2010). In 1931, NZ was struck by an earthquake centered on Napier. At this time, private earthquake insurance was available in NZ, but was voluntary (NZNSEE, 1993). Then, in 1937, with World War II looming, war damage was excluded from most private insurance contracts. Again, in 1942, NZ was hit by another damaging earthquake not far from the capital, and in 1944, the Earthquake and War Damage Commission was established; it is the historical precursor to the EQC.[12]

[12] Part of the motivation for this was the slow rates of repair following the 1931 and 1942 events (NZ Treasury 2015). In the years that followed NZ was hit by a number of disasters including an earthquake triggered tsunami in 1944, an earthquake in 1968 and a major landslip in 1979. The Earthquake Commission Act of 1993 redesigned the scheme. A major development was the phase-out of commercial properties. It also amalgamated the War Damage and Earthquake Fund and the Disaster and Landslip Fund as the Natural Disaster Fund. This is the fund EQC draws from to pay out on claims.

The EQC currently provides three forms of insurance cover to residential property owners: structure, land, and contents. These are insured to replacement value against natural hazards such as earthquake/tsunami, volcanic eruption, and landslip. Since 1980, out of 543,531 claims, 94.9% have been related to earthquakes. The cover for residential buildings provides the first NZ$ 100,000 of replacement value for each insured dwelling.[13] If the loss is greater, the private insurer is responsible for any over-cap repair costs. As we will focus the analysis below exclusively on structural damage claims (and not on contents or land), we only describe this aspect of EQC policy.[14] For each NZ$ 100 of property insured by the EQC, a levy is charged by the private insurer and sent to EQC. These premiums had been set at 0.0005% of the amount insured in 1993, and were tripled after the Canterbury earthquakes of 2010–11 to 0.0015%. More than 99% of homes are valued at more than NZ$ 100,000, so that in effect all pay the same amount to EQC for the building insurance it provides (NZ$ 150 per annum).[15]

In order to quantify the regressivity of the EQC building cover, we required a measure of the benefit delivered by the EQC scheme. There is value in the certainty of knowing one is insured regardless of whether that insurance is ever required, and some value in the indirect facilitation of the over-cap private natural hazard insurance market. Our analysis assumes that this value is equal for all participants in the scheme and we therefore ignore it. For the purposes of this analysis, the benefit is defined as actual payout to the owner for disaster damage. This is a plausible measure since virtually all homes in Christchurch were damaged in the Canterbury earthquake sequence, and if anything, homeowners of weaker

[13] A multi-unit residential building covered for fire damage would be insured through EQC for the first NZ$ 100,000 times the number of dwellings in the building.
[14] The details about land cover, uniquely covered in NZ, are significantly more complicated.
[15] Recall the building cover from EQC is capped at NZ$ 100,000 per dwelling.

socioeconomic backgrounds were located closer to the epicentre of the earthquake. Thus, the redistributive question is: Have wealthier homeowners received more money from EQC for building repair than their less well-off counterparts. To answer this question, we combined two datasets: EQC insurance claim data from the Canterbury Earthquake series of 2010–2011,[16] and census data from Statistics NZ. Table 2 reports the summary statistics of the dwelling-level dataset we used in our analysis.

Table 2: Summary Statistics - Property level data for the Canterbury EQ Series Dataset

	(1)	(2)	(3)	(4)
VARIABLES	mean	sd	min	max
Total Dwelling Payout	45,774	58,207	0	358,381
Dwelling Payout / # of Claims	26,254	31,503	0	344,101
Assessed Bldg Repair Costs	63,370	139,215	0	1.498e+07
# claims made on that address	1.538	0.734	1	7
# dwellings claimed for on that address	1.066	1.014	1	102
Building Value 10	319,991	240,102	43,844	2.091e+07
Dwelling adjusted Building Value 2010	303,682	150,233	1,120	1.752e+07

Note: This table contains summary statistics for the 94,687 properties for which we have insurance claim data relating to the Canterbury Earthquake Series. There were five earthquakes associated with a significant number of payments (04/09/2010, 26/12/2010, 22/02/2011, 13/06/2011, 23/12/2011). Most are associated with the first and third events. 7.2% of dwellings are in the rural meshblocks. All monetary amounts in NZ$.

We also made use of Statistics New Zealand data—it provided meshblock level information from the New Zealand Census, conducted in 2001, 2006 and 2013.[17] The average number of people residing in a meshblock in Canterbury was about 105. We were able to match each property to a meshblock, which allowed us to match the property-level data to the meshblock-level socioeconomic data available from the Census. For our initial analysis, we included a number of explanatory variables generated from the 2006 Census (since it preceded the earthquakes). We used data pertaining to the personal and household sections of the census, specifically; the proportion of the meshblock who identified as Māori (the indigenous people of NZ) or Pacifika (Pacific Islanders), of individuals who self-report as

[16] On September 4th, 2010, Canterbury was hit by a magnitude 7.1 earthquake. This was followed by a series of aftershocks, the most devastating of which was a 6.3 earthquake on February 22nd, 2011, which took 185 lives.
[17] A meshblock is the smallest unit for which Statistics New Zealand collects data, with boundaries related to population. Censuses are conducted every 5 years. The 2011 census was postponed to 2013 because of the earthquakes.

having been born overseas, and who self-report as having completed tertiary level education; the median household income per meshblock;[18] the change in the median household income between 2001 and 2006, the mean number of household members, and the proportion of the meshblock residents which self-report as not owning their house. These data are summarized in Table 3. In Canterbury, 4,516 meshblocks have at least one valued property with fully recorded claims relating to the 2010–2011 sequence of earthquakes, as well as the corresponding census information.

As a first step in investigating the distributional implications of the EQC cover, in figure 1, we graphed the payout data by property decile and income decile for all the claims arising out of the Canterbury Earthquake Series dataset. In the figure, we see that as the property decile increases, the average total building payout for the decile increases as well, with a sharpest increase for the tenth decile. This pattern is repeated in the panel on the right where we use median household income deciles.

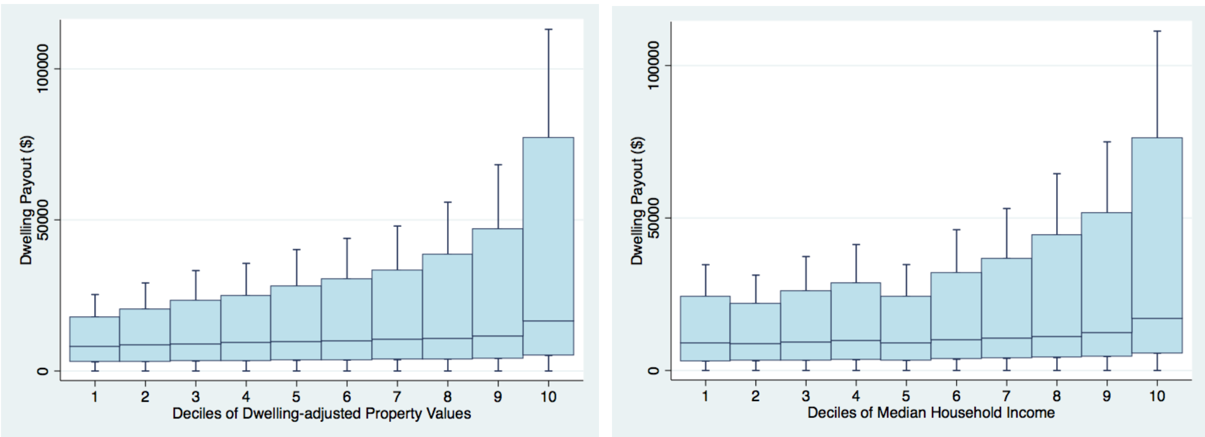

Figure 1: Distribution of Adjusted Building Payouts by Property Value and Income deciles. Canterbury dataset only, excludes zero value payouts. Distribution of payouts per property adjusted by number of dwellings insured by deciles of either dwelling adjusted modelled building value as at mid-2010, or meshblock level median household income as at 2006. Whiskers indicate 0.5 times the IQR, to better show the median values (version with standard whiskers in appendix).

[18] The top income is censored at $100,000. In 2006, there were 0.03% of meshblocks where the Med HH Income top censored at $100,000, and in 2001 0.01%.

In the boxplots, the middle line indicates the median, the shaded box indicates the interquartile range (IQR), and “whiskers" indicate 0.5 times the IQR. A notable observation is the increase in the spread of the total payout per dwelling as the deciles increase. This reflects higher-value properties require higher cost of repairs. It is worth reminding the reader here that these payouts only take into account the payouts from the public insurer, and significantly damaged homes would very likely have also received repair payouts from their private insurance company.

3. Methodology

Given the identical premiums paid for EQC cover by homeowners, we expected some redistribution to occur. We hypothesized two different mechanisms for the regressivity in this scheme:

1. Wealthier households may live in riskier areas (such as on hillsides or by the water), leading to a higher likelihood of natural hazard exposure, and thus to a higher likelihood of damage.
2. The 100K cap on building payments per event is likely to be more drawn on for wealthier homes since these homes have the capacity to incur more damage. Given the higher value of each component of the home, all else constant, high value homes will incur more damage.

The first mechanism is frequently mentioned as a plausible one for damages from floods, both from storm surges that hit coastal properties and from riverine floods that hit properties on riverbanks. This reason has been suggested as causing significant regressivity in the U.S. and UK flood insurance programs. While admittedly this has not yet been quantified in either of these flood insurance programs, it is less interesting from our perspective. It is less relevant for earthquakes, whose exact location and seismic-wave propagation are more random and less oriented with obvious external characteristics determining the spatial distribution of housing. In the case of the Canterbury earthquakes, the 22/2/2011 earthquake's epicentre was located to the southeast of the city; in general the eastern suburbs are less wealthy while the north-western suburbs, further away from the epicentre of the earthquake, have the higher value properties and higher-income households.

The focus of our analysis of the Canterbury experience was hence the second mechanism. The hypothesis we examined was that wealthier homeowners own properties that are likely to be costlier to repair than their less well-off counterparts. For example, a larger house usually has more interior floors that may crack, and these floors may be made from more expensive materials. Naturally, there are also possible mechanisms that can lead to the opposite outcome: perhaps newer or better-maintained houses are less vulnerable to earthquakes as they were built to higher seismic standards.

To identify the effect of the 100K cap, we first looked at whether higher-value homes in Canterbury sustained higher damages from the Canterbury Earthquake Series. In this case, wealthier homeowners were identified either by the value of the home or by the average socioeconomic status of the residents in the respective meshblock.[19] We regressed the

[19] Due to the nature of the available data, we could not identify whether a single homeowner owned multiple properties. Given this missing indicator of the particularly wealthy, our results are likely to be conservative. The identification based on a proxy for wealth (the value of the home) is potentially more informative than the distinction based on average income (per meshblock). The latter suffers, potentially, from the Ecologicial Fallacy (Robinson, 1950) – that the statistical correlation between two variables when they are grouped might be different from the statistical correlation of the individual members of these groups. Furthermore, although the property valuation spoke somewhat directly to the wealth of the homeowner, the census income data related to the residents of these meshblocks rather than the homeowners. Thus, for example, a "slum lord" who owned a number of cheaper properties in low socioeconomic areas could not be identified cleary. However, these are unlikely to be very important considerations as the majority of houses were owner occupied (67% of the 2006 Census stated occupied private dwellings were owner occupied).

assessed repair cost on the most recent valuation of the property, as well as a number of indicators of the socioeconomic level of residents, as indicated below:

$$Y_i = \alpha + \beta_1 PropertyValue_i + \beta_2 MedHHIncome_i + \gamma X_i + \varepsilon_i \qquad (1)$$

where $Y_i = TotalRepair_i$ is the sum of all assessed repair costs made for property *we* for claims related to earthquake events during the specified location (Canterbury) and time period (2010–2011). The error term, ε_i, is clustered at the meshblock level to account for some of our explanatory variables only varying at this aggregate level.[20] In a second specification, which better captures the regressivity of the EQC scheme as it is currently structured, the dependent (LHS) variable is the total payout on a property against the same covariates, including the most recent valuation of the property and a number of control variables at the meshblock level ($Y_i = TotalEQCpayout_i$). We estimated several alternative specifications to test the robustness of our results and to attempt to identify areas of variation that might require further analysis.

Given our focus on the distributional impact of EQ Cover, we also perform quantile regression on the Canterbury dataset, as below:

$$Y_i = \alpha + \beta_1 PropertyValue_i + \beta_2 MedHHIncome_i + \gamma X_i + \varepsilon_i \qquad (2)$$

4. Results and Discussion

Results are shown in Table 3. In columns 1–3, we used Total Actual Assessed Repair Costs as the dependent variable, and in columns 4–6 we used Adjusted Total Dwelling Payout.

[20] We estimate this with heteroscedastic and cluster robust standard errors (Cameron & Miller, 2015). We also performed this analysis at the claim level (rather than summing all claims for a single property). The results were very similar, and are available upon request.

Columns 1 and 4 show our comprehensive specifications. The first clear result is that the coefficients of interest (those on property value or median household income) are always positive and statistically significant at the 1% level. Their magnitude is such that for every NZ$ 1,000 of higher dwelling value, we found approximately a NZ$ 62.70 increase in Total Actual Assessed Repair cost, holding other factors constant, including median household income in the meshblock. Further, for every NZ$ 1,000 of higher building value, we found approximately $28.30 more to have been paid out from EQC to the homeowner. The association of higher values in these wealth/income indicators was more than twice as large for assessed repair costs than for the actual EQC payouts.

Table 4: Regression Results - Canterbury Earthquake Series

	(1)	(2)	(3)	**(4)**	(5)	(6)
VARIABLES		**Total Assessed Repair Costs**			**Total Dwelling Payout**	
Dwelling adjusted Building Value '10	**0.0577*** **	0.0671***		**0.0257*** **	0.0304***	
	(0.0145)	(0.0163)		**(0.00653)**	(0.00747)	
Median Household Income '06	**1.297*** **		1.404***	**0.662*** **		0.710***
	(0.149)		(0.147)	**(0.0713)**		(0.0707)
Dif. in Med HH Income '01-'06	**-0.839*** **	-0.0790	-0.896***	**-0.364*** **	0.0235	-0.390***
	(0.161)	(0.132)	(0.161)	**(0.0775)**	(0.0655)	(0.0776)
Proportion Tertiary Educated '06	**93,461*** **	178,205***	95,614***	**77,588*** **	120,855***	78,459***
	(18,081)	(17,336)	(18,144)	**(9,370)**	(8,856)	(9,388)
Proportion Not Homeowners '06	**-23,626** **	-55,219***	-25,703***	**-14,901*** **	-31,031***	-15,852***
	(9,344)	(9,579)	(9,316)	**(4,835)**	(4,824)	(4,810)
Mean Number of Household Members '06	**-32,364*** **	-12,728***	-31,872***	**-15,895*** **	-5,869***	-15,671***
	(4,100)	(3,599)	(4,101)	**(2,084)**	(1,915)	(2,083)
Proportion Māori '06	**102,156*** **	65,041**	92,382***	**84,528*** **	65,579***	80,172***
	(27,231)	(27,339)	(27,055)	**(15,261)**	(15,275)	(15,194)
Proportion Pasifika '06	**110,083*** **	81,959**	105,593***	**79,400*** **	65,041***	77,281***
	(37,144)	(37,533)	(37,110)	**(20,728)**	(20,948)	(20,705)
Proportion Born Overseas '06	**-22,657**	-46,174***	-22,376	**-19,178** **	-31,185***	-19,023**
	(16,017)	(16,277)	(15,999)	**(8,899)**	(9,037)	(8,879)
Rural Meshblock	**-46,007*** **	-45,428***	-44,539***	**-28,920*** **	-28,624***	-28,259***
	(2,733)	(2,721)	(2,699)	**(1,394)**	(1,392)	(1,384)
Constant	**61,067*** **	70,917***	72,808***	**38,727*** **	43,757***	43,941***
	(10,575)	(10,855)	(10,137)	**(5,427)**	(5,536)	(5,243)
Observations	**94,723**	94,723	94,799	**94,723**	94,723	94,799
R-squared	**0.040**	0.032	0.036	**0.079**	0.066	0.074

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

This table contains results from OLS regressions with meshblock level clustered standard errors. The dataset includes information on all claims made to the NZ EQC related to insured damages following the earthquakes in the Canterbury region for events from 2010-09-04 to 2012-02-11. The dataset is at the property level and excludes zero value claims (those which did not receive EQC funded repairs). The raw claims and portfolio data is confidential because of privacy concerns. The other explanatory variables are all gathered from publicly available Census tabulation from StatisticsNZ. These are meshblock level variables as collected from the 2006 (and for Median Household Income, 2001) Census.[21]

[21] The reader will note low R-squared values. However, this research did not set out to accurately predict damages or payouts, but to identify variations correlated with socioeconomic characteristics. A low R-squared is therefore not of concern in this context.

The effects of the meshblock-level explanatory variables were qualitatively the same for both dependent variables, and consistently affected the dependent variables in the expected directions. The growth in median HH income (2001 to 2006) had a negative effect when statistically significant; so that the "newer" the wealth in the area, the lower the assessed damage and EQC payout. It has been suggested in numerous media reports that because of the bureaucratic complexity of the insurance system, more educated claimants find it easier to navigate the system and successfully claim for higher damages. This hypothesis justifies the tertiary education measure we included as an explanatory variable. As hypothesized, the coefficient was positive and statistically significant. It has also been suggested that homeowner that live in the house are more likely to negotiate with the insurer to expedite the process (thus putting renters whose property was damaged at a disadvantage). This variable was statistically significant and negative as hypothesized. Another possible factor was the number of household members. As hypothesized larger household size, another imperfect proxy for socioeconomic status, was also negative and statistically significant.

We also included a number of ethnicity variables at the meshblock level. The Proportion Maori and Proportion Pasifika are included to check if the scheme is having an adverse effect on these minorities, which are of particular importance to New Zealand. In NZ, both ethnicities are identified with lower income, on average, though the Pasifika population (those originating from other Pacific Islands) are generally more disadvantaged, with a significant proportion using English as a second language. However, after controlling for income, education, and family size, which also proxy for socioeconomics, these ethnicities are statistically identified with positive effects on both damages and payouts. Finally, we also included the proportion of the population born overseas, as tabulated in the 2006 census, in case the claim process is more difficult for this group to navigate because of language barriers, fewer local social ties, lack of communication with assessors about deadlines, etc. The assessed repair costs are not significantly affected by this measure. However, there does appear to be a negative effect on total dwelling payouts. Finally, if the property is in a rural meshblock, we see negative effects on both damages and total payouts; likely because most rural meshblocks were further away from the quake's epicentre.

Table 5: Regression specification testing - Canterbury Earthquake Series

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES			Total Dwelling Payout			
Dwelling adjusted Building Value '10	**0.0257*****	**0.0269*****	**0.0269*****	**0.0282*****	**0.0264*****	**0.0264*****
	(0.00653)	**(0.00678)**	**(0.00678)**	**(0.00700)**	**(0.00647)**	**(0.00644)**
Median Household Income '06	**0.662*****	**0.473*****	**0.491*****	**0.729*****	**0.507*****	**0.504*****
	(0.0713)	**(0.0591)**	**(0.0582)**	**(0.0553)**	**(0.0502)**	**(0.0450)**
Dif. in Med HH Income '01-'06	-0.364***					
	(0.0775)					
Proportion Tertiary Educated '06	77,588***	85,462***	77,979***			
	(9,370)	(9,353)	(8,549)			
Proportion Not Homeowners '06	-14,901***	-18,594***	-21,511***	-8,876**	512.2	
	(4,835)	(4,858)	(4,540)	(4,428)	(4,317)	
Mean Number of Household Members '06	-15,895***	-14,299***	-15,102***	-17,301***		
	(2,084)	(2,087)	(2,041)	(2,066)		
Proportion Born Overseas '06	-19,178**	-20,625**				
	(8,899)	(8,933)				
Proportion Māori '06	84,528***	80,825***	89,274***	60,879***		
	(15,261)	(15,262)	(14,413)	(14,018)		
Proportion Pasifika '06	79,400***	75,247***	71,703***	52,096**		
	(20,728)	(20,814)	(20,799)	(20,778)		
Rural Meshblock	-28,920***	-28,863***	-28,077***	-31,257***	-34,118***	-34,147***
	(1,394)	(1,399)	(1,379)	(1,350)	(1,329)	(1,249)
Constant	38,727***	40,524***	39,145***	42,908***	13,849***	14,133***
	(5,427)	(5,455)	(5,467)	(5,514)	(3,847)	(2,555)
Observations	94,723	94,723	94,723	94,723	94,725	94,725
R-squared	0.079	0.076	0.075	0.064	0.053	0.053

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. This table contains results from OLS regressions with meshblock level clustered standard errors. The dataset includes information on claims made to the New Zealand Earthquake Commission related to Earthquakes or Fires following Earthquakes in the Canterbury region of New Zealand for events from 2010-09-04 to 2012-02-11. The dataset is at the property level and excludes unfunded claims. Raw data confidential. Data source: EQC. Total dwelling payout is an aggregate variable including both any cash settlement made to the property and any payout for managed repairs, divided by the number of dwellings insured on that property. Adjusted Building Value 10 is the building value for the portfolio, divided by the number of dwellings insured on the property. The other explanatory variables are all gathered from publicly available Census data from Statistics New Zealand. These are meshblock level variables as collected in the 2006 (and for Median Household Income, 2001) Census.

In Table 5, the consequences of progressively removing some of the explanatory variables are presented. In column (1) (identical to column (4) in Table 4) we see that all the explanatory variables are statistically significantly different from zero at the 1% level, with the exception of the population born overseas. We first removed the growth in median household income from 2001 to 2006, as this had a more tenuous theoretical effect on payouts; as presented in column (2). This resulted in a decrease in the effect of 2006 Median Household Income, and had a small positive effect on the coefficient for Building Value. In column (3) we removed the least statistically significant variable: the proportion of the meshblock born overseas. The coefficient on median household income increased slightly and became marginally more precise, while the effect of building value remained unchanged. Dropping the proportion of the tertiary in column (4) led to a sharp increase in the effect of median household income, corroborating the widely established observation that education and income are positively correlated, and showing that without controlling for education, we might overestimate the income effect.

Table 6: Quantile Regression Results

	(1)	(2)	(3)	(4)
		Quantile Regressions		**OLS Regression**
	0.25	0.5	0.75	
		Total Dwelling Payout		Total Dwelling Payout
VARIABLES				
Adjusted Building Value '10	**0.000322*** **	**0.0107*** **	**0.0739*** **	**0.0245*** **
	(1.83e-06)	**(0.00182)**	**(0.0106)**	**(0.00613)**
Median HH Income '06	**0.106*** **	**0.370*** **	**1.433*** **	**0.802*** **
	(0.00289)	**(0.0453)**	**(0.0688)**	**(0.0586)**
Dif. Med HH Income '01-'06	-0.0555***	-0.198***	-0.610***	-0.408***
	(0.00402)	(0.0367)	(0.109)	(0.0766)
Mean # of HH Members '06	-936.2***	-5,380***	-29,969***	-14,667***
	(45.35)	(527.0)	(2,533)	(1,951)
Rural Meshblock Indicator	-2,482***	-7,981***	-59,810***	-32,875***
	(72.28)	(348.8)	(3,249)	(1,227)
Constant	3,899	9,871***	72,701***	41,002***
	(0)	(2,850)	(7,791)	(4,473)
Observations	94,725	94,725	94,725	94,725
R-squared				0.064

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. This table contains results from quantile regressions with meshblock level clustered standard errors. The dataset includes information on all claims made to the NZ EQC related to insured damages following the earthquakes in the Canterbury region for events from 2010-09-04 to 2012-02-11. The dataset is at the property level and excludes zero value claims (those which did not receive EQC funded repairs). The raw claims and portfolio data is confidential because of privacy concerns. The other explanatory variables are all gathered from publicly available Census tabulation from StatisticsNZ. These are meshblock level variables as collected in the 2006 (and for Median Household Income, 2001) Census.

This also led to a slight increase in the effect of building value, and interestingly, also decreased the absolute values of the coefficients on the ethnicity measures. In column (5) we removed ethnicity and household member controls, bringing building value down marginally, median 2006 household income down sharply, and removing all statistical significance for the proportion not homeowners. Removing this last proportion in column (6) completed our robustness checks, with negligible effects on the coefficients of interest.

Our primary results remained robust throughout these checks. Tertiary education and changes in household income appeared the most closely correlated with median household income. The proportion not homeowners appeared to affect the dependent variable only through our other controls. There was clearly some cultural effect at work as well, since controlling for income and education increased the absolute value of the coefficients on ethnicity controls.

Columns 1-3 of Table 6 contain coefficients from regressions at different quantiles. In Column 1 are those pertaining to the 25th percentile. As the reader can see, the coefficients of interest are rather small but significant. On average, with a thousand-dollar increase in *Adjusted Building Value*, we would expect the 25th percentile of Total Dwelling Payout to increase by only 30c, all else equal. However, with a thousand-dollar increase in *Median Household Income* there would be on average a $100 increase in the 25th percentile of *Total Dwelling Payout*. In Column 2 see the effect on the median of *Total Dwelling Payout*, which are significantly higher than those for the 25th percentile, and in Column 3 the effect on the 75th percentile, which are higher again. Interestingly the coefficients of interest by OLS regression sit between the median and 75th quantile results.[22]

5. An easy solution to the regressivity problem

Unfortunately, we cannot define an actuarially fair premium structure given we do not know the distribution of the risk. However, nonetheless we can define possible remedies to the regressivity issue. One potential fix to the unfortunate regressivity of the NZ disaster insurance system is remarkably simple; rather than paying a flat premium per year, homeowners could be required to pay a set percentage of total private sum insured. This would reflect that homes with a larger sum insured are more likely to claim larger amounts, even of the $100,000 per dwelling, as shown in the analysis thus far. This modification would correct the regressivity issue.

To test this suggestion, we perform a numerical simulation on the Canterbury dataset. We simulate the premiums using the percentages adopted by EQC, but applied to the Dwelling-adjusted building value as opposed to the first $100,000 of these. This would move the scheme towards a more risk-based (as opposed to flat) premium structure.

First the suggested premiums for each property (by EQC Property Group) are created as *0.0005 x (Dwelling-adjusted building value as at mid-2010)*. Then, the same process is used but substituting 0.0005 for first 0.0015 and then 0.002. To explore what this would have meant for Canterbury building claimants, we build the distribution of these suggested

[22] we should note here that quantile coefficients tell us about effects on the distribution, not on individuals.

premiums within each decile of dwelling-adjusted building values. As shown in **Figure 2** below, annual premiums would have been slightly higher for those homeowners living in wealthier areas. However, they are by no means unaffordable.

Using the 0.0005% measure, for the first six deciles of properties by *Dwelling-adjusted Property Values*, suggested premiums per year would actually likely be lower than the current $150 per annum, and for no one does the suggested premium go above $400 per annum. A homeowner whose home was valued at $300,000 (and insured to that level) would pay $150 per year, whereas a homeowner whose home was valued at $1,000,000 would pay $500 per year. With the 0.0015% or 0.002% measures, the vast majority of homeowners would still pay less than $1000 per year.

With these 94722 homes, under the original premium structure EQC would have raised 4,736,100 in one year if all were single dwelling homes. With the suggested premiums, EQC would have raised 14,100,000 with the 5% measure, 42,200,000 with the 15% or 56,200,000 with the 20%. Thus, the premium change would likely also have financial benefits for EQC.

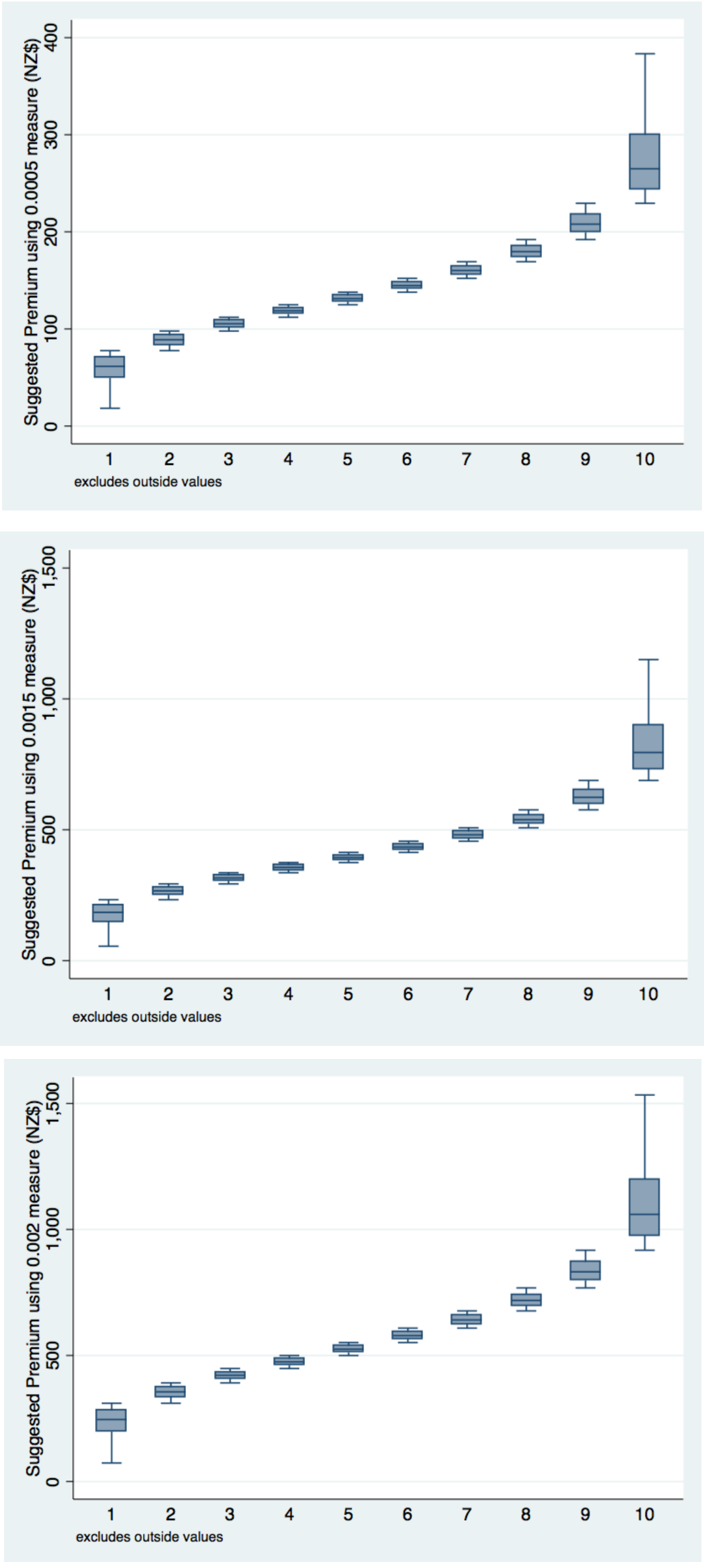

***Figure 2**: Distribution of suggested premiums.*

This figure shows the distribution of suggested premiums. The first is the distribution of premiums as 0.0005 times the dwelling-adjusted building value, the second using 0.0015 and the third using 0.002. The building values are as at mid-2010, and adjusted by the number of dwellings recorded. This figure also uses only the building claimants from the Canterbury 2010-2011 earthquake series. Data supplied by EQC, and confidential. Dollars are NZ$.

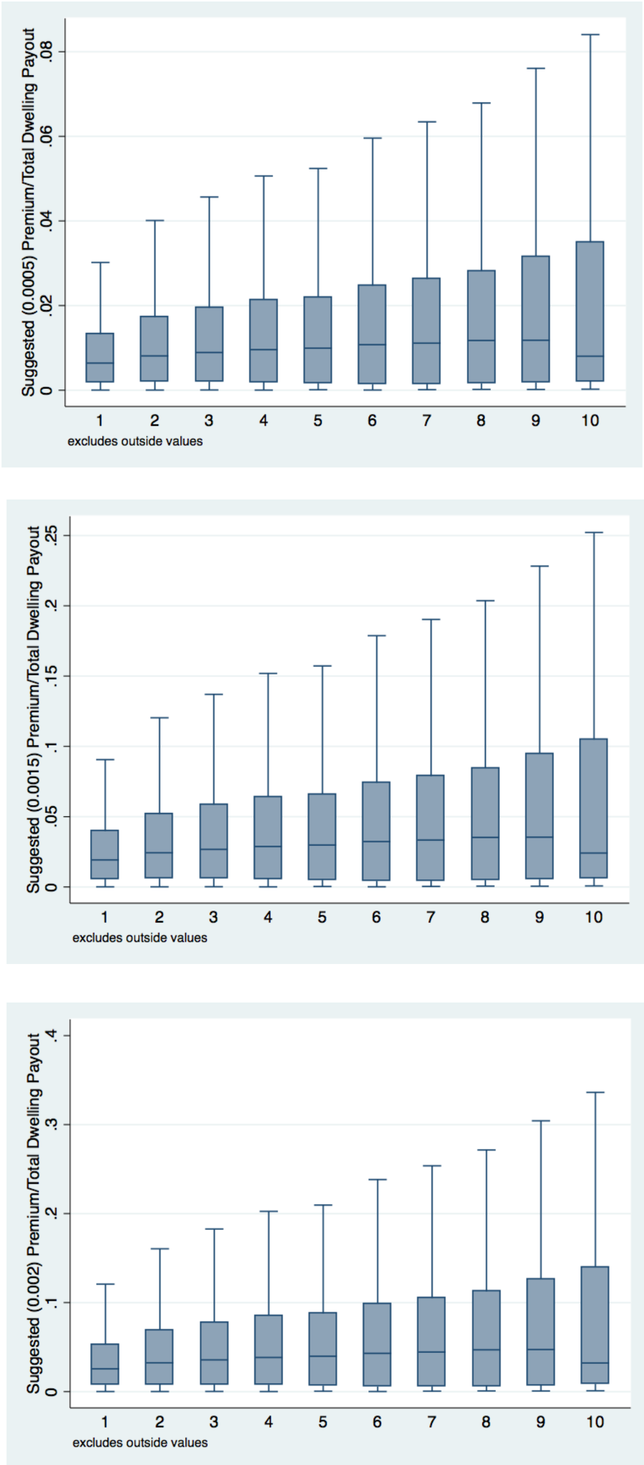

***Figure 3**: Premium to Payout Ratio for suggested premiums, by Building Value Decile*
This figure shows the distribution of Suggested Premium/Total Payout, where in panel 1 the suggested premium is calculated as 0.0005 times the dwelling-adjusted building value (pre quake), the second using 0.0015 and the third using 0.002. The building values are as at mid-2010. This figure also uses only the building claimants from the Canterbury 2010-2011 earthquake series. Data supplied by EQC, and confidential. Dollars are NZ$.

The hope with this progressive premium structure is that the ratio of premium to EQC payout becomes constant across deciles. In **Figure 3** below, these ratios of suggested premiums against actual payouts (per dwelling), are graphed in standard box and whisker plots by building value decile. The median ratio for each is relatively flat across deciles, supporting this as a possible fix to the regressivity issue. The suggested premium structure could be adjusted to make it more constant. Alternate graphs by Median Household Income decile are included in the Appendix, as are those showing the flat structure as it operates currently.

Any of the three suggested options of premium structure would make EQC's residential building cover scheme significantly less regressive. The choice of premium structure (using 0.0005, 0.0015 or 0.002) would depend on the requirements for income raised per year and the capability of homeowners at the lower end of the spectrum to afford increased premiums. The 0.0005 measure reduces regressivity, increases EQC revenue per year, and does not increase annual premiums for homeowners of the lowest decile of valued homes. This measure is therefore preferred by the authors.

6. Conclusions

In almost all cases where homeowners are exposed to a significant risk of sudden-onset natural hazards, the private insurance sector elects not to insure against these hazards.[23] Direct public provision or subsidization of insurance are therefore necessary if such cover is perceived to be socially desirable. Unfortunately, public natural hazard insurance has

[23] The many reasons why this is the case are discussed in Kusuma et al. (2017).

adverse distributional consequences in almost all cases. This paper's aim is not only to describe the socioeconomic direction in which these insurance-related financial transfers are flowing, but to quantify them. The mechanism for wealth transfer in public earthquake insurance analyzed in this paper facilitates upward transfers—the poor are subsidizing the rich.

Our analysis of the Canterbury Earthquake series, and the functioning of New Zealand's public insurer, offers two insights. First, it clearly supports the hypothesis that more expensive homes receive higher payouts irrespective of their exposure to the hazard; i.e., higher sums that are a direct consequence of the higher value of the affected properties. Secondly, it suggests that capping coverage and having flat premiums, both of which aim to deliver a more equitable scheme, are not sufficient; even these kinds of programs end up transferring risk from homeowners of expensive homes to homeowners of lower-value homes (and in some other cases to non-homeowners). Our finding in the New Zealand case, suggests that many other seemingly more egalitarian natural hazard insurance systems are regressive as well.

With this work, we aim to improve the functionality of public natural hazard insurance, by drawing attention to the distributional function of these schemes. In the New Zealand case, the regressive effect can be counteracted by a simple shift from effectively flat premiums to a set percentage of the total private sum insured (while maintaining the coverage cap). Future research should extend this type of analysis to other public natural hazard insurance schemes in other countries, so that the adverse distributional characteristic of these programs is avoided.

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Appendix 1 : Suggested Premium to Total Payout ratios by alternate deciles

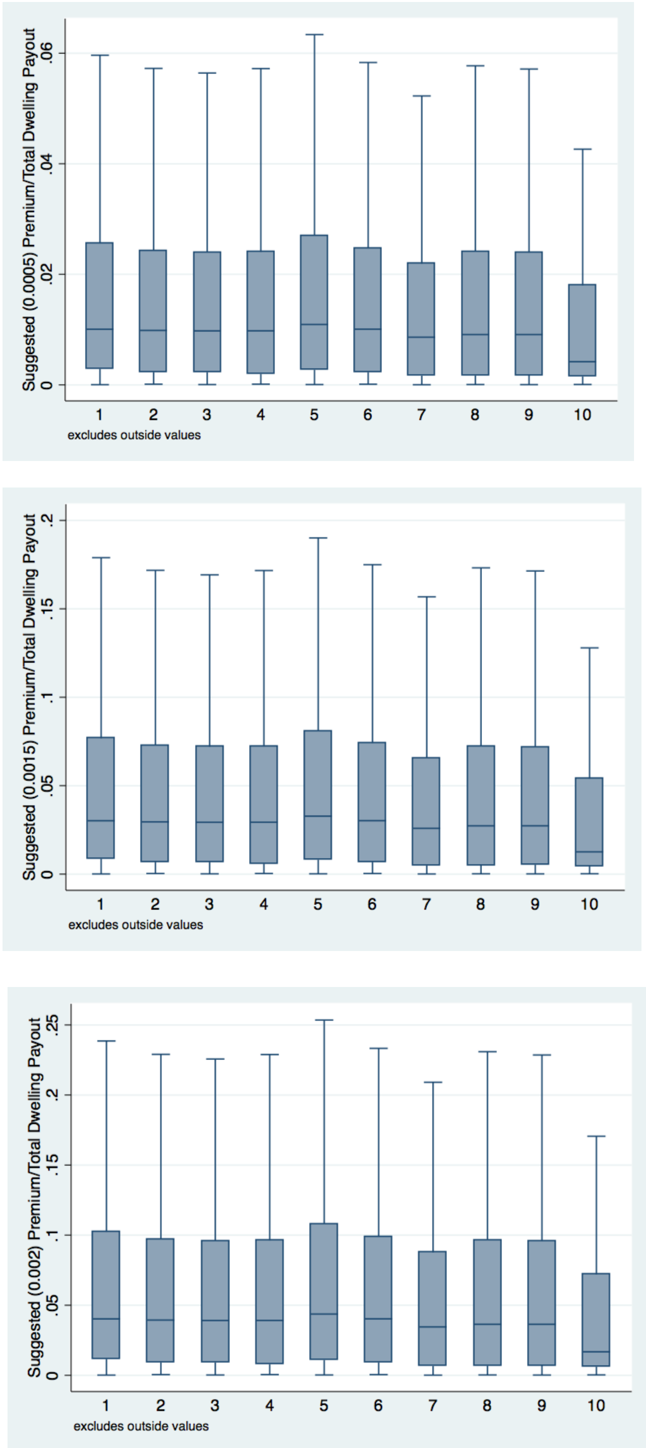


Figure 4: *Premium to Payout Ratio for suggested premiums, by Median Household Income Deciles.* In panel 1 the suggested premium is calculated as 0.0005 times the dwelling-adjusted building value (pre quake), the second using 0.0015 and the third using 0.002. The Median Houehold Income values are at the meshblock level, and as at 2006. This figure also uses only the properties of building claimants from the Canterbury 2010-2011 earthquake series. Property and payout data supplied by EQC and confidential, income data collected by Statistics New Zealand in the 2006 Census. Dollars are NZ$.

Appendix 2: $150/Total Payout ratios, by property value and income deciles

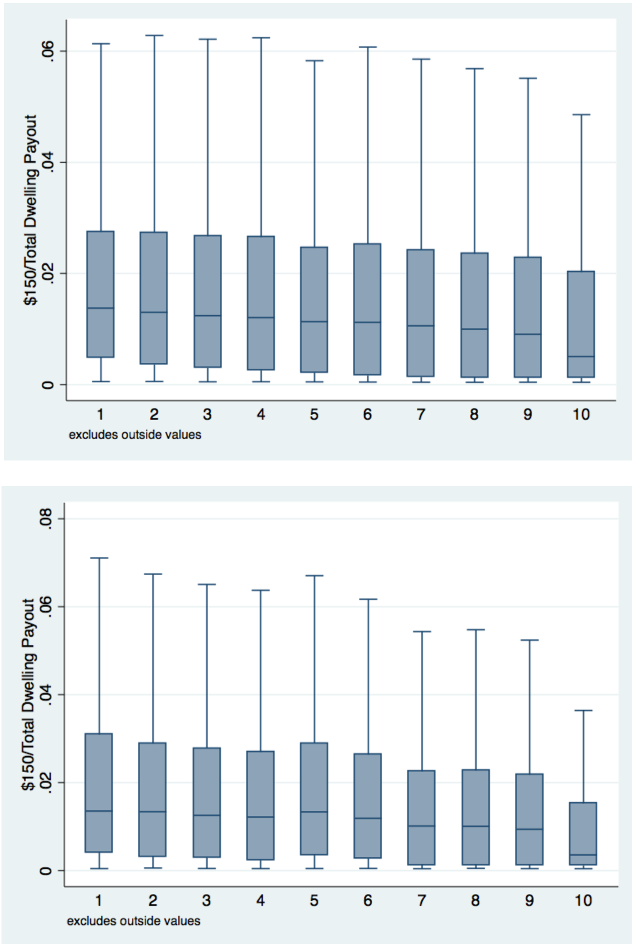
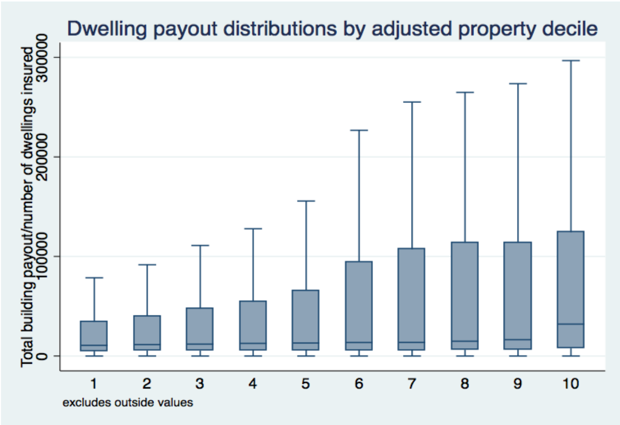


Figure 5: *$150/Total Building Payout by Building Value Decile then Median Household Income Decile*

In panel 1 the suggested premium is calculated as 0.0005 times the dwelling-adjusted building value (pre quake), the second using 0.0015 and the third using 0.002. The building values are as at mid-2010. The Median Household Income values are at the meshblock level, and as at 2006. This figure also uses only the properties of building claimants from the Canterbury 2010-2011 earthquake series. Property and payout data supplied by EQC and confidential, income data collected by Statistics New Zealand in the 2006 Census. Dollars are NZ$. “Excludes outside values" refers to the outliers of the box and whisker plots being omitted.

Appendix 3



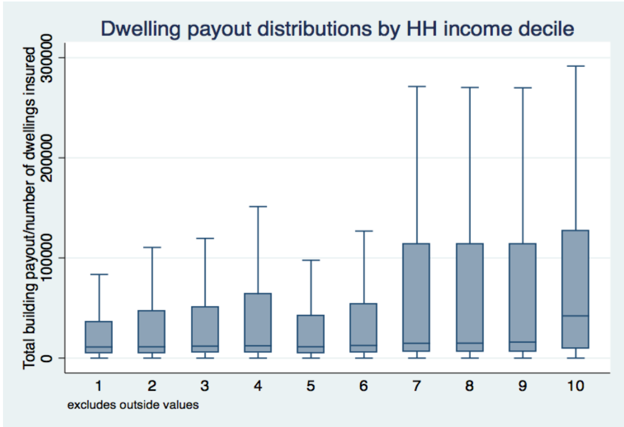


Figure 6: *Distribution of Adjusted Building Payouts by Property Value and Income deciles – version 2* Standard Box and Whisker Plots - Canterbury dataset only, excludes zero value payouts. Distribution of payouts per property adjusted by number of dwellings insured by deciles of either dwelling adjusted modelled building value as at mid-2010, or meshblock level median household income as at 2006.