

The impact of the Canterbury earthquakes on household income and expenditure in the Canterbury region in New Zealand

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Abstract. Using New Zealand's Integrated Data Infrastructure (IDI), we evaluate the impacts of the 2010-2011 Canterbury earthquakes on household economic behaviour, focusing on changes in income and expenditure. We link data from the Household Economic Survey (HES) linked to measures of administrative address histories and meshblock-level earthquake intensity, and implement a propensity-score-matched difference-in-differences (PSM-DiD) design comparing pre and post earthquake outcomes for earthquake affected exposed Canterbury households with a matched comparison group. We find that, relative to matched comparison North Island households, we find that total and regular household income increase by approximately 7,000-7,900 New Zealand Dollars (NZD) in both low- and high-intensity areas increases by about NZD 7,600 in the post earthquake period. Total expenditure shows no clear average DiD effect, but expenditure's composition shifts markedly: changes substantially. In high-intensity areas, receipts and refunds, which capture an HES category that includes insurance reimbursements and related inflows, more than double, and while spending on general insurance, transportation, telecommunications, diary-recorded day-to-day spending rises by about 14%. Spending also increases in transportation, travel purchases, fees and subscriptions, and social insurance contributions. Additional analysis shows that also increases. Expenditure responses are broader among above-median-income households that relocated out of than among below-median-income households. Households later observed outside Canterbury faced substantially higher have housing costs (around NZD 25,000) higher and lower mortgage and loan repayments (payments around NZD 9,500) 600 lower than households that remained remain, while average incomes conditional income differences are similar across the two groups statistically insignificant. These findings provide evidence on

~~household economic adjustment to disasters and offer policy-relevant insights into show that~~
post-disaster ~~financial support, social security design,~~ income growth can coexist with
~~heterogeneous recovery costs~~ and ~~the management of population movements,~~ substantial changes
in household expenditure.

1. Introduction

Disasters such as earthquakes, floods, and cyclones impose large and persistent economic costs. Beyond damage to housing and infrastructure, major shocks disrupt employment, reallocate income sources, and force difficult choices about consumption, saving, and relocation. Understanding these household-level adjustments is essential for evaluating disaster relief, social protection, insurance ~~arrangements~~, and the incidence of disaster-related losses.

The 2010–2011 Canterbury earthquakes in New Zealand provide a ~~stark~~
~~illustration particularly informative setting~~. A sequence of major earthquakes caused extensive residential damage, prompted large-scale ~~red~~ land-zoning ~~decisions~~ and demolition, and triggered an unprecedented reconstruction programme in and around Christchurch. The institutional environment was also distinctive: ~~residential~~ insurance coverage was ~~near universal~~ widespread, public and private compensation flows were ~~sizable~~ substantial, and the rebuild generated strong local labour demand over several years. Together, these features make the Canterbury earthquakes an informative case for studying how households adjust income and expenditure after a large but geographically concentrated shock.

A substantial macroeconomic and regional literature has documented how disasters affect aggregate output and local growth. Cross-country and regional studies find persistent level losses alongside reconstruction-driven ~~boom~~ expansions, with ~~heterogeneous~~ effects ~~varying~~ considerably across events and locations (e.g. Cavallo et al., 2013; Noy and duPont, 2018). More recent work using quasi-experimental designs and high-resolution data has refined estimates of local impacts and recovery dynamics (~~Dube et al., 2023~~), ~~Roth Tran & Wilson, 2025~~). Using municipality-level panels and a synthetic-control design, duPont et al. (2015) document long-lived regional economic costs after the Kobe earthquake, consistent with persistent ~~economic~~

scarring. These perspectives, however, ~~are largely silent~~ provide limited evidence on how aggregate recovery patterns ~~map onto~~ translate into household behaviour and welfare.

Household- and individual-level evidence remains comparatively limited. ~~U.S. studies following Hurricane Katrina and other events document sharp,~~ but existing studies demonstrate that recovery paths can diverge sharply across households and institutional settings. Carter et al. (2007) show that severe environmental shocks can generate persistent asset losses and poverty-trap dynamics among vulnerable households in Ethiopia and Honduras. By contrast, Gignoux and Menéndez (2016) find that earthquake-exposed households in rural Indonesia experienced short-run economic losses followed by medium-run recovery and, in some cases, longer-run income and welfare gains. U.S. studies following Hurricane Katrina and other disasters document substantial changes in migration, labour supply, and income trajectories, with outcomes varying across demographic groups and locations (Groen and Polivka, 2010; Deryugina et al., 2018). Work on household balance sheets and credit markets further shows that disasters can trigger substantial portfolio re-optimisation, ~~with~~ involving interactions ~~between~~ among insurance, debt, and government transfers that are largely invisible in ~~macro~~ macroeconomic aggregates (Gallagher and Hartley, 2017). ~~Yet there is still~~ Nevertheless, relatively little evidence exists on how disasters reshape the composition of household spending across detailed categories, including ~~essentials, housing costs, and insurance-related flows~~ routine consumption, housing costs, insurance-related flows, debt repayment, and retirement saving. An additional limitation of much of the existing literature is that insurance settlements and other compensatory inflows are often combined with household income or are not observed separately. The HES allows us to distinguish regular household income from receipts and refunds recorded in the expenditure accounts, a category that includes insurance reimbursements and related inflows.

For New Zealand, ~~micro~~ microeconomic evidence on the Canterbury earthquakes has begun to emerge. Existing research documents ~~macro~~ macroeconomic and sectoral consequences of the rebuild, including construction-led productivity gains and the reallocation of economic activity within Christchurch (Parker and Steenkamp, 2012; Wood et al., 2016). More recent work uses administrative microdata to track individual incomes and labour-market trajectories in the

affected region, highlighting heterogeneous impacts across sectors and along the income distribution (Abdeljawad and Noy, 2025a, 2025b). However, this literature does not directly analyse household-level income and expenditure responses using nationally representative survey data, nor does it examine in detail how the composition of spending changes across [expenditure](#) categories and household types.

This paper addresses three questions. First, did the Canterbury earthquakes change household income and the composition of [spendingexpenditure](#) for households located in exposed areas relative to matched households in comparable unexposed areas? Second, how did these responses vary across the income distribution and with earthquake intensity within Canterbury? Third, how did income and expenditure [responsesoutcomes](#) differ between households that remained in Canterbury and those that relocated elsewhere after the earthquakes?

To answer these questions, we link the Household Economic Survey (HES) to administrative data within the Integrated Data Infrastructure (IDI). [The HES component is analysed as a repeated cross-section, and we compare changes in average household outcomes across survey waves.](#) Using [Inland Revenue](#)linked administrative address histories and meshblock-level Modified Mercalli Intensity (MMI)-measures, we [define-exposedidentify](#) households whose reference person lived in Canterbury at the time of the earthquakes and construct a matched comparison group [outside Canterbury-from households that consistently resided in the North Island.](#) Propensity-score matching [balances pre-earthquake characteristics, and is conducted separately within each survey wave.](#) We then implement a difference-in-differences design¹, supplemented by an event-study [specification—comparespecifications and joint pre-trend tests,](#) [to compare](#) pre- and post-earthquake outcomes [while exploiting variation over time and across intensity levelsexposure groups.](#)

The main results are as follows. [Household incomes in the most severely affected parts of Canterbury increased.](#) Both total household income and regular household income increased for [earthquake-exposed Canterbury households](#) relative to the matched comparison group [in the post-earthquake years, consistent with heightened labour demand during the.](#) The estimated [effects are similar in magnitude in the low- and high-intensity groups, suggesting that the income response reflects broader regional recovery and reconstruction period, alongside disaster related](#)

~~support and compensation mechanisms that improved households' overall financial positions.~~
~~dynamics rather than a simple linear relationship between local ground-shaking intensity and~~
~~household income.~~

Total household expenditure shows no clear average ~~DiD~~difference-in-differences effect, ~~but,~~
~~However,~~ expenditure composition ~~shifts markedly. High-income households in changes~~
~~substantially. In~~ high-intensity areas ~~increase spending on~~, significant increases appear in
~~receipts and refunds, general insurance, transportation, travel, fees and subscriptions, and social~~
~~insurance contributions, while low-income households primarily adjust spending~~
~~on telecommunications, diary items (i.e., items recorded via the HES two-week expenditure~~
~~diary, largely small day-to-day purchases). As expected, insurance payouts and reimbursements,~~
~~fees and subscriptions, education, recreation, sport and culture, and household maintenance.~~
~~Housing costs increase significantly in low-intensity areas, while fees and subscriptions increase~~
~~for in both income groups, with a markedly larger rise among high intensity groups. These results~~
~~indicate that households adjusted through multiple channels, including insurance and~~
~~reimbursement activity, routine consumption, mobility, communication, housing and~~
~~maintenance expenditure, and subscription- and service-related spending.~~

~~The composition of adjustment also differs markedly by household income. Above-median-~~
~~income households— exhibit relatively broad expenditure responses across insurance-related~~
~~flows, housing and maintenance, telecommunications, miscellaneous payments, and fees and~~
~~subscriptions. Below-median-income households show a narrower pattern, with significant~~
~~changes concentrated in receipts and refunds, medical and health expenditure, diary-recorded~~
~~purchases, and travel. Insurance- and refund-related entries increase for both income groups, but~~
~~the estimated response is substantially larger among above-median-income households,~~
~~consistent with differences in asset ownership, insurance depth, and claim size.~~

Finally, among exposed households, those ~~that relocate out of~~ later observed outside Canterbury
face substantially higher housing costs and lower mortgage and loan ~~repayments~~expenditure than
~~those households that remain; conditional on observable characteristics such as~~ in the region.
Conditional on age, sex, and household size, ~~average incomes are similar across~~ the two groups
do not differ significantly in total income, regular income, or total expenditure. Because

relocation is self-selected, these estimates are interpreted as descriptive conditional associations rather than causal effects of migration.

This paper contributes to the disaster and household-finance literatures in three ways. First, it provides new ~~causal~~ quasi-experimental evidence on household income and expenditure following the Canterbury earthquakes' impacts on household incomes and spending earthquakes using nationally representative microdata, complementing survey data linked to administrative residential histories. This complements existing macroeconomic and individual-level administrative studies. ~~Second, by disaggregating expenditure into detailed categories and examining heterogeneity by income and migration status, it sheds light on post-disaster adjustment channels and distributional consequences across changes at the household types.~~ Third, it illustrates how survey data linked to administrative records within the IDI can be combined with propensity score matching and modern DiD methods to study localized shocks level.

~~Second, by disaggregating expenditure into detailed categories and examining heterogeneity by income, earthquake intensity, and migration status, the paper identifies adjustment mechanisms that are obscured by aggregate measures of income and total expenditure. In particular, it distinguishes regular household income from receipts and refunds recorded separately in the HES, including insurance reimbursements and related compensatory inflows. This distinction helps separate labour-market and recurring-income responses from insurance- and compensation-related financial flows, while also identifying changes in routine consumption, housing expenditure, mobility costs, debt commitments, and longer-term financial contributions.~~

Third, the paper illustrates how repeated cross-sectional survey data can be combined with administrative records, geographically detailed hazard measures, propensity-score matching, and difference-in-differences methods to study geographically localised shocks. The approach to reconstructing pre-disaster residence from multiple linked address sources is also applicable to other household-level research conducted within the IDI.

The remainder of the paper is structured as follows. Section 2 presents the empirical strategy, including the difference-in-differences framework, ~~the event study specification, the~~ propensity

-score matching procedure, [event-study specification](#), and [the identification assumptions-alternative weighting estimator](#). Section 3 describes the data sources and linkage, [outlines the construction of the treatment and control-comparison groups using address histories](#), and [earthquake intensity measures, and defines the key the](#) income and expenditure outcomes. Section 4 reports descriptive evidence on [pre- and post-earthquake patterns in](#) household characteristics, income, [and spending, and documents exposure gradients by intensity-expenditure, and post-earthquake relocation](#). Section 5 presents the main [causal estimates-and](#) heterogeneity analyses [by income group, earthquake intensity, and post-earthquake migration status, alongside](#), and robustness checks. Section 6 discusses [interpretationthe findings](#) and limitations, [draws policy implications, and concludes before concluding](#).

2. Methodology

2.1 Difference-in-differences

Difference-in-differences (DiD) is a widely used econometric design for estimating the causal effects of policy changes or exogenous shocks on outcomes of interest when randomised controlled trials are infeasible. The basic idea is to compare changes in outcomes over time for an exposed (treated) group relative to a suitable comparison (control) group, thereby netting out time-invariant differences between groups and shocks common to all units in a given period (Wing et al., 2018).

[The HES is analysed as a repeated cross-section rather than a household panel. The index i therefore denotes households observed in survey wave t, not the same household followed over time. The DiD estimator compares changes in average outcomes for exposed and matched comparison households across waves.](#) In this study, we use DiD to estimate the causal impact of the 2010 – 2011 Canterbury earthquake sequence on household income and expenditure. We treat the earthquakes as an exogenous shock and exploit cross-regional variation in earthquake intensity to classify households into exposure groups. By interacting this intensity-based

exposure measure with an indicator for the post-earthquake period, we estimate how household income and expenditure evolved with different levels of seismic exposure.

The conventional DiD approach relies on the parallel trends assumption: in the absence of the shock, exposed and comparison households would have followed similar trajectories over time. Under this assumption, the difference in changes between the two groups can be interpreted as the causal effect of the earthquakes (Angrist and Pischke, 2009). In our empirical specifications, we include region fixed effects and year fixed effects to account for time-invariant regional characteristics and year-specific shocks shared by all households.

Finally, because disaster impacts plausibly vary with exposure intensity, we follow recent contributions in the disaster economics literature and incorporate earthquake intensity into heterogeneous DiD specifications (e.g. Abdeljawad and Noy, 2025a, 2025b). Specifically, we interact earthquake intensity with the post-earthquake indicator to estimate how the effects on household income and expenditure differ across intensity levels.

In summary, the regression model adopted in this study takes the following form:

$$Y_{it} = \alpha + \beta_1(LowMMI_i \times Post_t) + \beta_2(HighMMI_i \times Post_t) + \gamma_1 Age_{it} + \gamma_2 HHSize_{it} + \mu_r + \epsilon_{irt} \quad (1)$$

Here, Y_{it} denotes the outcome (dependent) variables, including *Total Household Expenditure*, *Total Household Income*, *Total Household Regular Income* and different expenditure categories, where i indexes HES households and t indexes survey years. $LowMMI_i$ and $HighMMI_i$ are indicators for identify treated Canterbury households located in meshblocks assigned to the low- and high-intensity groups/categories, respectively. The omitted category comprises households in unexposed meshblocks ($MMI = 0$), is the matched North Island comparison group, so β_1 and β_2 are interpreted relative to the unexposed baseline. $Post_t$ is a post-earthquake dummy variable, taking the value of 1 for the years 2011/12 and onward, and 0 otherwise. Age_{it} denotes the age of the household reference person, and $HHSize_{it}$ denotes (For total and detailed expenditure outcomes, the first available post-earthquake full-expenditure wave is 2012/13, because the full expenditure module is only available in 2006/07, 2009/10, 2012/13 and 2015/16.)

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X_{it} includes the age of the household reference person, age squared, the reference person's sex, and household size.

The regression model controls for year fixed effects λ_t and region fixed effects μ_r , where the regions are defined at the Territorial Authority (TA) level, in order to account for spatial correlation and regional heterogeneity. To ensure robustness in statistical inference, standard errors are clustered at the TA level to adjust for potential intra-regional correlation in household income and expenditure outcomes (Bertrand et al., 2004).

2.2 Propensity score matching

To improve the control group's suitability as a counterfactual to the earthquake-affected households group, we construct a control group that closely resembles the earthquake-treated group in terms of observable pre-earthquake household characteristics that are predetermined or slow-moving relative to the earthquake shock. This facilitates a more credible assessment of the causal effects of the earthquakes on household income and expenditure. Following standard practice in the disaster economics literature (Bondonio & Greenbaum, 2018; Yan, Zhou & Qi, 2025), we employ PSM to select an appropriate control sample.

To respect the Stable Unit Treatment Value Assumption (SUTVA), in particular its no-interference component, which requires that treatment effects on treated units do not spill over to control units, we restrict attention to households that were never exposed to the Canterbury earthquake sequence. We draw on existing research indicating that the impacts of the earthquakes were largely confined to the Canterbury region and its immediate surroundings (Parker & Steenkamp, 2012; Wood et al., 2016). Accordingly, when constructing the control group we exclude all households located in the South Island, as well as those that had migrated out of the Canterbury region. The control pool therefore consists only of households that consistently resided in the North Island over the sample period.

During the matching stage, we estimate each household's propensity to reside in Christchurch belong to the Canterbury treated group in 2010 using a logit model based on key pre-earthquake demographic characteristics. Specifically, the propensity score p_i for household i is obtained from the following logit specification:

$$Pr(D_i = 1 | X_i) = p_i = \frac{e^{X_i\beta}}{1 + e^{X_i\beta}} \quad (2)$$

where $D_i=1$ if household i was located in Canterbury in 2010, and $D_i=0$ if it was located in the North Island. The vector X_i contains pre-earthquake household-level covariates. On the basis of the estimated propensity scores, we implement 1:2 nearest-neighbour matching without replacement, matching each treated household with two North Island households that serve as control observations.

To enhance matching quality, we impose a strict caliper restriction (caliper = 0.2) on the propensity score distance to ensure a high degree of similarity in the covariate space for variables unlikely to be influenced by the earthquakes, including the age of the household reference person, household size, the reference person's gender, and their highest educational qualification. Moreover, all matches are required to fall within the same survey year in order to eliminate potential confounding arising from inter-year variation (Austin, 2011a).

To evaluate the quality of the matching, we assess covariate balance for each survey year from 2006/07 to 2017/18 using two standard diagnostics: the standardized mean difference (SMD) and the variance ratio (VR). Across all years, the matched samples satisfy commonly used balance criteria: all SMD values are below 0.1 and the variance ratios for continuous variables are below 2 (see Appendix B), indicating a high level of covariate balance and satisfactory matching performance (Stuart, 2010).

On this basis, we obtain a high-quality control group pool that underpins the subsequent DiD estimates and strengthens the identification of the causal effects of the Canterbury earthquakes on household income and expenditure. Table 1 reports, for each survey year, the number of treated households, the size of the eligible control pool used for matching, and the final number of matched control households selected through PSM. These figures confirm that efficient matching was consistently achieved across all years (Austin, 2011a; Austin, 2011b; Stuart, 2010).

Table 1. Sample sizes of treated households, eligible control pool, and matched controls by survey year

Survey Year	Treated Households	Eligible control pool	Matched control households
2006/07	417	1512	831
2007/08	462	1917	924
2008/09	459	1887	921
2009/10	432	1692	867
2010/11	432	1971	867
2011/12	486	1938	972
2012/13	411	1608	822
2013/14	438	1896	873
2014/15	705	3135	1407
2015/16	420	1995	840
2016/17	456	2118	909
2017/18	633	3165	1263

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Besides, because matching is conducted separately within each survey wave, treated households are compared with contemporaneously matched controls rather than with a single pooled comparison group. To further assess whether compositional changes across waves threaten identification, we estimate pseudo-outcome balance tests using key household characteristics and broad household-composition categories as outcomes. The $Treat \times Post$ coefficients are small and statistically insignificant for the main covariates and for broad household-composition groups, suggesting that the matched treated and control samples do not exhibit systematic differential compositional shifts after the earthquakes. The four-cell means and pseudo-outcome tests are reported in Appendix B.

2.3 Examining the parallel trends assumption

A key assumption of the DiD design is that, in the absence of the earthquake shock, treated and control groups would have followed parallel trends. To assess this assumption, we estimate an event-study specification that traces the dynamic effects before and after the earthquakes.

In this specification, we interact the treatment-group indicator with a full set of year dummies, using 2006/07 as the omitted (base) year. This allows us to recover the trajectory of treatment effects over time. The regressions control for key household covariates, including the age, age^2 , sex of the reference person, and household size, and include two-way fixed effects for

year and region. Robust standard errors are clustered at the territorial authority level to account for within-area correlation in the error terms and to ensure valid inference.

It is important to note that each wave of the HES runs from July of one year to June of the next, and is therefore labelled as a "cross-year" survey. For example, "2006/07" refers to interviews conducted between July 2006 and June 2007. Although the magnitude 7.1 earthquake on 4 September 2010 was substantial, the most severe destruction resulted from the major aftershock on 22 February 2011, which caused extensive loss of life and property and had a shallower epicentre much closer to the Christchurch city centre.

The 22 February 2011 event severely disrupted data collection. For instance, the 2011 Census, originally scheduled for March 2011 (shortly after the most damaging earthquake), was postponed to 2013. Many of the most severely affected households were therefore not captured in the 2010/11 HES wave. In this study, we accordingly classify the 2006/07 – 2010/11 survey waves as the pre-earthquake period and the 2011/12 – 2017/18 waves as the post-earthquake period.

Furthermore, documentation from Stats NZ indicates substantial differences in how expenditure data were collected across HES waves. In the 2006/07, 2009/10, 2012/13 and 2015/16 waves, the total household expenditure variable aggregates spending across all categories. In the remaining waves, however, this variable covers only housing-related costs, such as rent, mortgage payments, local authority rates and building insurance. As a result, comparability in total expenditure across waves is limited and the series is affected by changes in data-collection methods and sampling design. Given these inconsistencies, we restrict our analysis of total household expenditure to the 2006/07, 2009/10, 2012/13 and 2015/16 waves.

Appendix C presents event-study ~~plots~~estimates for total household income, regular household income, and total household expenditure. ~~In~~For the ~~five income outcomes, the omitted reference period is 2006/07, and the~~ pre-earthquake ~~waves (2006/07 – 2010/11), the estimated~~ interaction coefficients ~~for all three outcomes~~correspond to the 2007/08, 2008/09, 2009/10, and 2010/11 survey waves. These coefficients fluctuate around zero and ~~their confidence intervals~~ consistently include ~~are individually imprecisely estimated. Joint Wald tests also fail to reject~~

the null hypothesis that the four pre-earthquake coefficients are jointly equal to zero, indicating no systematic pre-trends and supporting the validity for total household income ($p=0.814$) and regular household income ($p=0.624$).

For total household expenditure, comparable full-expenditure data are available only in 2006/07, 2009/10, 2012/13, and 2015/16. The pre-earthquake comparison is therefore limited to the 2009/10 interaction coefficient relative to the 2006/07 reference wave. This coefficient is not statistically significant, and the corresponding Wald test fails to reject the null of the parallel trends assumption no pre-earthquake difference ($p=0.544$). Because only one comparable pre-earthquake expenditure coefficient is available, the evidence for expenditure is necessarily weaker than for the two income outcomes.

Taken together, Figures C.1 C.3 present the event-study estimates that not only confirm the validity of and joint pre-trend tests provide supportive evidence for the parallel trends assumption in the pre. The post-earthquake period, income coefficients become positive in several later survey waves, while the total-expenditure coefficients remain positive but also reveal a canonical imprecisely estimated.

2.4 Alternative weighting estimator: ATT-IPW robustness check

As an additional robustness check, we estimate an inverse-probability-weighted DiD pattern (Aizer, 2003; Clarke & Tapia Schythe, 2021) specification targeting the average treatment effect on the treated group experiences systematic and statistically significant (ATT). This exercise assesses whether the main PSM-DiD results are sensitive to the nearest-neighbour matching procedure and to the exclusion of unmatched comparison households.

The ATT-IPW estimator uses the same treated group and eligible North Island control pool as the baseline design. However, instead of selecting a matched subset of control households, it retains the full eligible comparison pool and reweights control households according to their estimated propensity scores. This provides a complementary estimator: the baseline PSM specification compares treated households with close contemporaneous controls, while the ATT-IPW specification uses a broader comparison sample but gives greater weight to control households that are more similar to the treated group.

For the ATT-IPW specification, we estimate propensity scores using an augmented version of the core balancing covariates, including the age of the household reference person, age squared, household size, the reference person's sex, and highest educational qualification. In richer robustness specifications, we also include housing tenure and broad household-composition categories.

For the ATT-IPW estimator, treated households receive weight one, while control households receive weights proportional to:

$$w_i = \frac{e(X_i)}{1-e(X_i)} \quad (3)$$

where $e(X_i)$ is the estimated propensity score. The weighted control group is therefore reweighted to resemble the distribution of observed covariates among treated households. We then estimate the same DiD outcome specification as in Section 2.1, using these ATT-IPW weights. Standard errors are clustered at the Territorial Authority level, as in the main analysis.

For total household expenditure and detailed expenditure categories, the ATT-IPW specification follows the same sample restriction as the baseline expenditure analysis: only the full-expenditure HES waves, namely 2006/07, 2009/10, 2012/13 and 2015/16, are used. Income outcomes are estimated using all annual HES waves from 2006/07 to 2017/18.

We report the ATT-IPW estimates as an appendix robustness check rather than as the preferred baseline estimator. The baseline PSM-DiD design offers a more transparent comparison between treated households and close contemporaneous controls within each survey wave, while the ATT-IPW estimator relies more heavily on model-based reweighting of the full eligible control pool. Nevertheless, ATT-IPW is useful for assessing whether the estimated effects are driven by the specific matching algorithm or by the exclusion of unmatched control households.

To evaluate the ATT-IPW specification, we conduct three diagnostic checks. First, we examine covariate balance after weighting using standardized mean differences and variance ratios. Second, we inspect the distribution of estimated weights to assess whether the results are driven by extreme weights or weak common support. Third, we compare the main PSM-DiD estimates with a sequence of bridge specifications that progressively move from the baseline PSM model

to the full ATT-IPW model. This bridge exercise helps identify whether changes in ~~income and expenditure following the earthquakes, whereas the control group exhibits no comparable shifts.~~ statistical precision arise from additional covariate controls, the use of a larger control pool, or the weighting estimator itself.

The ATT-IPW estimates should therefore be interpreted as a complementary robustness exercise. When the ATT-IPW coefficients remain similar in sign and magnitude to the PSM-DiD estimates but are less precisely estimated, this suggests that the substantive interpretation of the results is not driven by the baseline matching procedure, even though statistical precision varies across estimators.

3. Data

3.1 Data sources and treated group identification~~method~~

The Household Economic Survey is a nationwide survey conducted annually by Stats NZ to measure households' economic conditions, including income, housing costs and living expenditures. Information on total household income and regular income is collected every year. By contrast, the full expenditure module is fielded only once every three years: in the 2006/07, 2009/10, 2012/13 and 2015/16 waves. In the remaining years, the annual questionnaire covers income and housing costs only. Accordingly, our analysis of detailed expenditure relies exclusively on these four waves. Because HES households are not followed as a balanced panel, we treat the survey as a repeated cross-section. The household observations in different waves should therefore be interpreted as wave-specific samples rather than repeated observations of the same households.

A key challenge in identifying the impact of the earthquakes lies in defining the treated group, households that were residing in the Canterbury region at the time of the earthquakes and were therefore directly exposed to the seismic shock. Because households may have relocated for various reasons before or after the earthquakes, the residential address recorded in the HES when the survey was conducted does not necessarily reflect their location at the time of the disaster.

To address this, we combine multiple administrative data sources to reconstruct the residential history of each household reference person over time.

Specifically, each household reference person in the HES sample is linked, via their unique identifier (snz_uid), to address records from five administrative sources: Inland Revenue (IR), Accident Compensation Corporation (ACC), the Ministry of Social Development (MSD), the Household Labour Force Survey (HLFS) and the cross-agency address notification dataset (address_notify). The address reference period is defined as 1 January 2010 to 22 February 2011—the date of the main earthquake—hereafter referred to as the ["treated-period-pre-earthquake address reference window"](#)¹.

By combining administrative address data with residential information from the HES survey year, we classify all sample households into four groups.

Group 1 consists of households whose HES survey address is in Canterbury and whose last registered administrative address prior to the earthquakes is also in Canterbury. These households were living in the affected area both before the earthquakes and at the time of the survey, and are therefore included in the treated group. For around 20% of household reference persons, the region code of their most recent pre-earthquake address is missing. In these cases, if the most recent non-missing pre-earthquake address and the first post-earthquake address are located in the same meshblock in Canterbury, we also classify the household as having resided in Canterbury at the time of the earthquakes and allocate it to Group 1.

Group 2 comprises households whose HES survey address is outside Canterbury but whose last administrative address prior to the earthquakes is in Canterbury. These households are treated as part of the treated group unless there is clear evidence that they had relocated before the earthquakes. Specifically, a small number of Group 2 households whose HES interview date

¹The IR dataset records only address changes and does not include observations when an address remains unchanged. As a result, households that stayed at the same address throughout the [treated-period address reference window](#) would not have any corresponding record in the IR [system for the treated-period address reference window](#), which may lead to the erroneous exclusion of households that were in fact stably residing in the Canterbury region during this period. To mitigate this potential bias, we relax the address timestamp requirement for cases in which address information is available only from the IR source and is absent from all other sources. For these IR-only cases, we extend the acceptable timeframe for the most recent address record back to 1 January 2000, effectively retaining [up to ten more than eleven](#) years of historical address data in order to recover pre-earthquake residential information as accurately as possible.

falls after the date of their last administrative address record and whose HES survey address is outside Canterbury are excluded from the treated group, as they are likely to have moved out of Canterbury before the earthquakes. [The remaining Group 2 households are retained because the linked address information indicates Canterbury residence immediately before the earthquakes, even though they are later observed outside Canterbury in the HES.](#)

Group 3 comprises households whose HES survey address is in Canterbury but whose last administrative address prior to the earthquakes is outside Canterbury. These households are likely to be post-quake in-migrants to the earthquake-affected region, and are therefore excluded from the treated and control groups.

Group 4 includes households whose HES survey address and pre-earthquake administrative address are both outside Canterbury. These households were not directly exposed to the disaster and are included in the control-group pool if they resided in the North Island (and excluded altogether if they resided in the South Island).

Under this classification, the treated group consists only of households for which there is reliable evidence that the reference person resided in Canterbury at the time of the earthquakes, while the control group comprises households that have never been recorded as living in Canterbury in any of the linked address sources.

Group sizes vary across waves. Group 1 includes 387-648 households per wave; Groups 2 and 3 are small (typically 12-66 and 12-63 households, respectively; suppressed in some waves); and Group 4 is the largest group (1,890-3,774 households per wave). The full year-by-year distribution is reported in Table A.1 Appendix A.

3.2 Analysis of missing address rates

Despite linking HES records to multiple administrative datasets, pre-earthquake addresses cannot be recovered for a non-trivial share of households. Across survey waves, the share of reference persons with no usable pre-earthquake address record ranges from about 15 to 19 percent, with no evidence of a systematic time trend. This suggests that the missing-address problem is persistent but relatively stable over time, rather than being driven by earthquake-

related disruptions in a particular survey year. Table A.2 in Appendix A reports the year-by-year unmatched rates.

To assess whether these missing-address rates primarily reflect limitations of our linkage procedure or more general structural features of the underlying data, we perform a parallel exercise using the 2013 Census. Linking Census records to Inland Revenue address histories yields unmatched rates of roughly 11 to 23 percent across HES survey years, a pattern that is very similar in magnitude and timing to the rates observed for the HES sample itself (Table A.3 in Appendix A). This close correspondence suggests that the missing-address problem is largely driven by the nature of the administrative address data, rather than by the specific way in which HES records were linked.

Further analysis and discussions with Stats NZ indicate that the unmatched cases can be broadly divided into two groups. The first consists of young adults whose address histories are genuinely short or incomplete: in the HES these reference persons are often under age 22, have recently left the parental home, and are still transitioning between study and work, so that few reliable historical addresses are available. The second group comprises hard-to-track individuals, including those with very frequent moves, intermittent labour-market attachment, or periods of living overseas. These individuals are systematically more likely to have missing or inconsistent address records in both administrative data and Census linkages.

The fact that similar unmatched rates are observed in both the HES-linked sample and the standalone Census linkage, and that the unmatched cases cluster in these two specific demographic groups, increases confidence that the missing-address issue does not introduce arbitrary selection into the treated and control groups. While non-random missingness at the extreme margins cannot be ruled out, the patterns are logically coherent and consistent across multiple data sources and survey waves. ~~This suggests~~ These patterns reduce, although they do not eliminate, concerns that the remaining missing-address cases do not pose a substantial threat to the validity of the study's conclusions ~~histories are driving the main results.~~

3.3 Variable definition and construction

The level of earthquake intensity experienced by each household is measured using the MMI scale. To capture earthquake exposure, we utilise high-resolution seismic observation data for the February 2011 earthquake provided by New Zealand's national earthquake monitoring agency, GeoNet. These data are spatially overlaid with meshblock boundaries, small geographic units defined by Stats NZ, to construct a meshblock-level map of maximum ground-shaking intensity. Each household in the sample is then matched to its corresponding meshblock, yielding a household-level MMI value that serves as the key treatment-intensity indicator in our earthquake-exposure-heterogeneity analysis.

Earthquake exposure is categorised ~~into three groups: among treated Canterbury households in meshblocks with~~ using meshblock-level $MMI < 4$ ~~are assigned to the control group; To distinguish substantively meaningful shaking from very weak exposure, we exclude treated households with MMI values below 4. This lower bound is consistent with earthquake early-warning research that evaluates operational target intensities beginning at approximately MMI 4 – 4.5 (Saunders et al., 2022). Among the remaining treated households,~~ those with MMI values in the range $[4, 7)$ form the low-intensity group; ~~and, while those with $MMI \geq 7$ form the high-intensity group. This classification follows practical thresholds commonly used in~~ The threshold at MMI 7 is consistent with the disaster management literature (e.g. Kaiser et al., 2012; Saunders et al., 2022) and effectively distinguishes between areas that experienced mild shaking and those with potentially severe New Zealand MMI scale: MMI 4 is generally noticed indoors, whereas MMI 7 is associated with general alarm, difficulty standing, movement of furniture, and more substantial physical damage (GeoNet, n.d.). The terms “low” and “high” therefore describe relative exposure within the treated Canterbury sample. The comparison group consists of matched North Island households that were not exposed to the Canterbury earthquake sequence and serves as the omitted category in the DiD specifications.

Although all treated-group households are identified from administrative records as residing in the Canterbury region prior to the earthquakes, the number of households that can ultimately be matched to MMI intensity data is slightly smaller than the total treated group. This reflects two main factors, discussed below.

First, a small number of households that are classified as treated based on their Canterbury residence are located in meshblocks with MMI values below 4, reflecting greater distance from the earthquake's epicentre, lower modelled ground-shaking intensity. Second, some households have confirmed pre-earthquake administrative addresses in Canterbury but lack corresponding meshblock-level geographic identifiers. For these units, no precise spatial match can be performed and no MMI value can be assigned. Together, these two subsets account for only a small fraction of the treated group and are excluded solely from the heterogeneity analysis conducted later in the study.

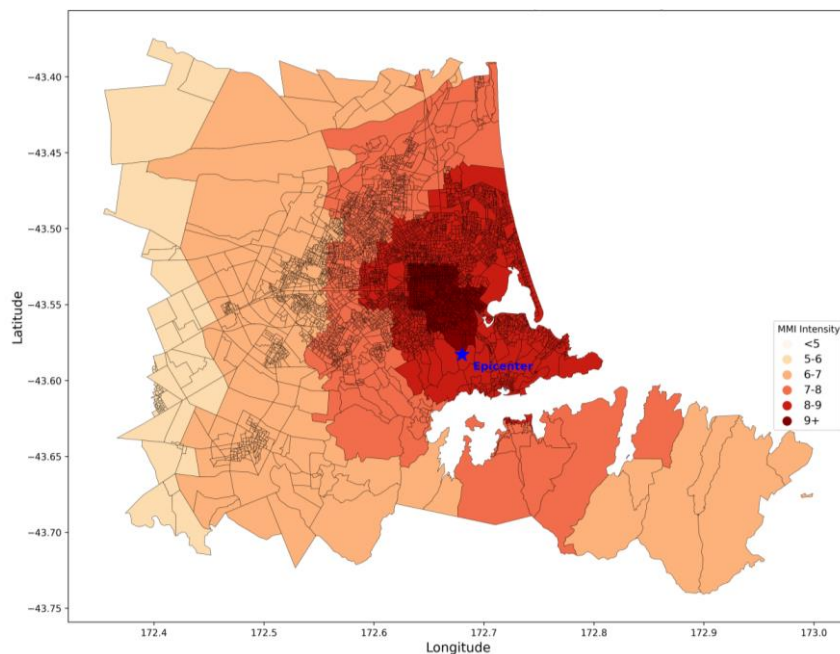


Figure 1. Meshblock-level earthquake intensity (MMI) in Christchurch City

Note: The figure displays a meshblock-level map of maximum Modified Mercalli Intensity (MMI) for the 22 February 2011 earthquake, constructed using shaking data from GeoNet and meshblock boundaries from Stats NZ. Darker shading indicates higher earthquake intensity and thus closer proximity to the epicentre, stronger ground shaking. The location of the 22 February 2011 epicentre is marked with a blue asterisk.

In addition to earthquake intensity, we also consider ~~households~~'households' homeownership status as a supplementary indicator of economic stability and post-disaster recovery capacity. We construct a binary variable with two categories: "owned/trust", which includes dwellings directly owned by household members or held through a family trust (a relatively common arrangement in Aotearoa New Zealand); and "rented", which includes market rentals, public or social housing, and other non-ownership occupancy arrangements.

This distinction is particularly important in the context of disaster resilience. Existing studies show that homeowners typically possess more assets and have better access to credit, which supports stronger recovery resilience and a greater capacity to mobilise resources following a disaster (Sawada & Shimizutani, 2008). By contrast, renting households are more likely to face liquidity constraints and housing insecurity, potentially limiting their ability to adjust economic behaviour in response to shocks. ~~Including homeownership status as a control variable thus enhances the explanatory power of the model and allows us to identify potential heterogeneity in disaster impacts across different forms of property tenure~~We use this variable to describe pre-existing differences in housing stability and as an additional control in the robustness specifications. In specifications where tenure is included as an additional control, results should be interpreted as conditional on this housing-status dimension.

For the expenditure analysis, we follow the HES classification and divide total household expenditure into 18 categories that together cover both routine and longer-term expenses. These categories are: domestic fuel and power; housing costs; receipts and refunds; general insurance; miscellaneous payments; mortgages and loans; other property; transportation; ~~retirement-savings and~~ contribution schemes; medical and health; diary ~~(expenditure diary items); recorded day-to-day purchases;~~ travel; telecommunications; fees and subscriptions; education, recreation, sport and culture; household operations; household maintenance; and credit and debit accounts. As discussed in Section 2.3, the definition of total household expenditure differs across HES waves; we therefore restrict total-expenditure analyses to 2006/07, 2009/10, 2012/13 and 2015/16.

It is important to note that the HES employs three different data-collection methods for different types of expenditure:

1. Expenditure diary: Respondents record ~~each~~ small and easily forgotten ~~purchase~~ purchases over ~~seven~~ consecutive ~~7-day period (days, with the diary to be completed within 14 days)~~. ~~There is no minimum or maximum amount for diary entries, and all entries. We use the~~ annualised diary-derived expenditure values supplied in the HES. According to the HES documentation, these amounts are annualised using a ~~fixed~~ factor of 26.07.

2. Expenditure questionnaire - most recent payment: This module is used for infrequent, periodic or fixed large payments. Interviewers may verify bills on-site or ask respondents for immediate estimates. Reported amounts are annualised using frequency-specific factors—for example, weekly ($\times 52$), fortnightly ($\times 26$), monthly ($\times 12$), annually ($\times 1$) or every four weeks ($\times 13$).

3. Expenditure questionnaire - past 12 months: This module retrospectively captures expenditures that may have occurred sporadically over the previous year.

4. Descriptive ~~Statistics~~ Evidence

To clarify the relationship between earthquake exposure and household economic characteristics, the descriptive analysis is organised into two subsections: a cross-sectional comparison by earthquake intensity and control-group status (Section 4.1), and an analysis of heterogeneity within the treated group that compares households who remained in place with those who relocated (Section 4.2). ~~These descriptive comparisons are not interpreted causally; rather, they~~ provide context for the DiD estimates reported in Section 5.

In constructing the summary statistics, we treat variables as follows. The age of the reference person and household size are reported as arithmetic means, as is standard in the descriptive-statistics literature and because these variables are bounded and not driven by extreme outliers. By contrast, total household income, regular income, total expenditure and housing expenditure are summarised using medians to reduce the influence of outliers, ~~such as including very high-net worth and net~~ income households ~~and households with unusually low or negative reported income~~.

For mortgages and loans, a large proportion of households report zero or missing values, so the median is equal to zero in most years and provides little discriminatory power. We therefore

report the mean for this variable, which better reflects the average level of mortgage and loan payments among households with positive expenditure. ~~This approach follows standard practice in New Zealand's official statistics when dealing with left-censored consumption items.~~

4.1 By earthquake intensity and control-group status

Table D.1 in Appendix D reports key characteristics of the sample across groups, including the average age of the reference person, household size, the share of female reference persons, and the homeownership rate. The high-intensity group ($\text{MMI} \geq 7$) has a slightly lower average age of the reference person than both the low-intensity and control groups (mean age: High = 51.5; Low = 54.6; Control = 52.7). This pattern may reflect the greater presence of younger households in central urban areas, which were also exposed to higher seismic intensity, but the differences are modest and should be interpreted with caution.

There are more pronounced differences in homeownership status. Across all survey years, the share of households that own their dwelling or hold it in a family trust is approximately 10 percentage points lower in the high-intensity group than in the low-intensity group, whereas ~~the difference~~ differences between the treated and matched control groups ~~is not statistically significant~~ are less pronounced. This pattern is consistent with the concentration of rental housing in central urban areas, which were also among the locations most severely affected by the 2011 earthquake (Kaiser et al., 2012).

4.2 Heterogeneity within the treated group: stayers versus relocators

To further explore differences in household responses to the earthquakes, we divide the treated group into two categories. The "stay" group consists of households whose HES survey-year address and last pre-earthquake administrative address are both located in the Canterbury region. The "relocation" group comprises households whose post-earthquake HES survey address is outside Canterbury, but whose last pre-earthquake administrative address was within the region².

² The relocation group does not exclusively represent post-earthquake out-migrants. By construction, it includes households whose HES survey address lies outside Canterbury while their last administrative address prior to the earthquakes is in Canterbury, and who therefore are treated as having been resident in the affected area immediately before the disaster. There is a small subset of cases in which the HES interview date falls after the date of the last recorded administrative address and the HES survey address is outside Canterbury. For these households, there is evidence that they may have moved out of Canterbury before the earthquakes; we therefore exclude them from the treated group to avoid misclassification.

When defining relocation, we classify households based on the combination of their location at the time of the earthquakes (using administrative address records for January 2010 – February 2011) and their location at the time of each HES interview. Households in the relocation group are those whose reference person lived in Canterbury immediately before the earthquakes but are later observed in HES interviews residing outside Canterbury. In contrast, the ~~stayed~~stay group comprises households whose reference person remained in Canterbury both at the time of the earthquakes and at the time of interview. In the post-earthquake waves (2011/12 – 2017/18), the relocation group therefore primarily captures households that moved out after the earthquakes.

As shown in Table D.2 in Appendix D, the average age of reference persons in the stay group is generally higher than in the relocation group across most survey years. This pattern suggests that migration behaviour is more prevalent among relatively younger individuals, consistent with international evidence on post-disaster migration (Fussell, 2015).

There are also sizeable differences in homeownership. In the post-earthquake years, the homeownership rate in the stay group is generally around or above 70%, whereas in the relocation group it fluctuates around 50%. This suggests that households remaining in Canterbury tend to enjoy greater housing stability, while households that relocate are more likely to be in rental or temporary accommodation.

In terms of income, ~~both total and regular household income medians are consistently higher for the stay group in most years, indicating that~~ relocation households ~~tend to face more fragile income conditions. They have lower median income than stay households in several years and exhibit larger dispersion in some waves. However, these descriptive differences should be interpreted cautiously because the~~ relocation group ~~also exhibits larger standard deviations in income, reflecting greater income heterogeneity~~ is small in many waves and migration is self-selected.

For expenditure, the two groups display broadly similar medians in total and housing-related spending across most years. However, there are pronounced differences in the mortgages-and-

loans variable, with the stay group consistently reporting higher values. This pattern is consistent with these households being more commonly owner-occupiers in the mortgage repayment phase.

Taken together, ~~relocation~~the descriptive evidence suggests that relocated households display weaker economic profiles than differ from stay households in most survey years. Regardless of whether they moved before or along several dimensions, especially age, homeownership and housing-related expenditure. These differences are consistent with selective mobility after the earthquakes, ~~these households tend to experience greater income volatility and housing insecurity. While migration is self-selected and this pattern does~~but they should not imply be interpreted as evidence that relocation itself causes vulnerability, it does highlight a strong correlation between mobility and economic disadvantage caused weaker economic outcomes.

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5. Results

5.1 DiD Results for income

As shown in Table 2, both total household income and regular household income increase significantly for households in high-intensity earthquake-exposed areas. On average relative to the matched control group. For total household income, households in these areas the low-intensity group experience an increase of around NZD 7,626.043 in total income ($p < 0.05$) and the post-earthquake period, while households in the high-intensity group experience an increase of around NZD 7,426 in regular income. Both total income ($p < 0.10$). By contrast, the estimated effects for low-intensity areas estimates are also positive but not statistically significant at the 5% level. For regular household income, the estimated increase is around NZD 7,924 for the low-intensity group and around NZD 7,412 for the high-intensity group, with the former statistically significant at the 1% level and the latter at the 5% level.

These findings contrast with the conventional view that disasters primarily exert negative economic effects as the earthquakes were associated with higher household incomes in the most severely affected areas. The possible mechanisms underlying this pattern are explored in the following sections.

The specification reported in Table 2 includes age, age squared, the sex of the reference person and household size as household-level controls. The positive income effects observed in both low- and high-intensity areas suggest that post-earthquake income gains were not confined only to the most severely shaken locations. The similarity in magnitude between the low- and high-intensity estimates further suggests that the income response may reflect broader regional recovery and reconstruction dynamics rather than a strictly monotonic relationship between local shaking intensity and household income gains.

Table 2. DiD results for total and regular household income

Variable	Total Household Income	Total Regular Household Income
MMI group:Low × Post	4799.547043.47* (3022.602889.43)	5277.877924.42** (2878.502673.83)
MMI group:High × Post	7626.42**7251.79* (3444.073559.44)	7426.387411.86* (3333.843286.86)
Age of reference person	-147.183810.44*** (39.27301.28)	-168.103462.94*** (39.13295.27)
Age ²	-37.83*** (3.03)	-34.60*** (2.97)
Sex of reference person	-11894.36*** (991.53)	-11689.34*** (944.59)
Household size	15328.4214074.52*** (683.89740.65)	14905.4613960.68*** (669.27718.84)

Observations: 17,202193

***p < 0.05, **p < 0.01, *p < 0.05, ***p < 0.001

Each column reports coefficients from a separate DiD regression. Robust standard errors clustered at the Territorial Authority (TA) level are in parentheses. Year and TA fixed effects are included. The positive coefficient on age and the negative coefficient on age squared are consistent with a concave life-cycle income profile, while the positive coefficient on household size reflects the fact that larger households typically have more potential earners. The negative coefficient on the sex of the reference person should be interpreted as a household-level association, rather than as an individual-level gender effect, since it may capture broader differences in household structure and income arrangements.

This pattern can be understood in light of the distinction between aggregate output measures and household-level outcomes. Although disasters are often associated with output losses, regional

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GDP in Canterbury did not fall markedly after the earthquakes (Stats NZ, [2023b2023](#)). In this setting, a large reconstruction programme and related labour-demand effects provide a plausible channel through which household incomes could rise in the post-earthquake period, particularly in the years following the shock (e.g. Wood et al., 2016). [The fact that regular household income also increases supports the interpretation that labour-market and earnings-related channels are likely to be important, rather than the results being driven solely by one-off compensation or insurance-related inflows.](#)

Second, post-disaster migration may affect the observed income distribution through compositional change. In our linked-address classification, the treated group includes only households for which there is reliable evidence that the reference person resided in Canterbury at the time of the earthquakes (Groups 1 and 2), while likely post-earthquake in-migrants to Canterbury are excluded (Group 3). As a result, migration-related compositional effects in our estimates operate primarily through selective out-migration among pre-earthquake residents ~~(Group 2)~~ and differences between stayers and movers, rather than through in-migration into the affected region. For example, if lower-income [or more housing-insecure](#) households ~~are~~ [were](#) more likely to leave Canterbury ~~due to housing damage or heightened housing insecurity, the median income among those remaining can rise~~ [after the earthquakes, the average observed income profile of exposed households could change](#) even without broad-based income gains. ~~This mechanism is consistent with patterns in our descriptive statistics. In addition, inflows from insurance payouts, particularly important in New Zealand given near universal earthquake insurance coverage, as well as government assistance programmes may have boosted households' disposable income following the disaster. Selective out migration may also affect the observed income distribution through compositional change, for all households.~~ Consistent with this possibility, Section 4.2 (and [Appendix D2](#)) documents [Table D.2 document](#) that households observed outside Canterbury after the earthquakes tend to be younger, [and](#) less likely to own their home, ~~and to have weaker income profiles~~ than those who remain. ~~As Section 5.4 therefore examines stayers and relocators separately as a result, the median income among remaining households can rise even without broad based income gains~~ [descriptive heterogeneity analysis.](#)

Existing literature provides complementary evidence on these mechanisms. [Dube, Roth](#) Tran and Wilson ([2023](#)[2025](#)) show that in the United States, per capita income in disaster-affected counties increased by an average of 0.5% over the eight years following a disaster, with some areas, such as those impacted by Hurricane Katrina, experiencing increases of more than 3%. The mechanisms they highlight include job growth in construction and related sectors, higher average wages, and inflows of insurance payouts and government reconstruction funds. These mechanisms align with the interpretation of our findings, suggesting that in settings with substantial reconstruction activity and compensation flows, household incomes may increase even as disasters impose large welfare losses through ~~other channel~~[housing damage, displacement and disruption](#).

It is important to emphasise that the spatial distribution and group-specific heterogeneity of post-earthquake income changes remain important avenues for future research. Given the repeated cross-sectional structure of the HES and sample-size constraints, especially the small number of households in Groups 2 and 3 in each wave, this study cannot fully characterise differential recovery trajectories by ~~income group~~, ethnicity, [income source](#), housing tenure, [household structure](#) or social capital. Future work leveraging longitudinal micro-level tracking in the IDI could provide more granular evidence on changes in the income distribution and the inequality implications of large natural hazards (Abdeljawad and Noy, [2025b](#)[2025a](#)).

5.2 DiD results for expenditure

In contrast to the income results, the DiD estimates for total household expenditure are positive but not statistically significant in either the low- or high-intensity group (Table 3). ~~However, when total expenditure is disaggregated into categories~~[The estimated coefficient is around NZD 3,414 for the low-intensity group and around NZD 2,011 for the high-intensity group, but both estimates are imprecisely estimated. The control variables display plausible expenditure patterns: age and age squared indicate a concave life-cycle profile for household expenditure, household size is positively associated with total expenditure, and the sex of the reference person is also significantly associated with expenditure levels. However, the absence of statistically significant average treatment effects for total expenditure suggests that the earthquakes did not generate a clear overall increase in aggregate household spending. When total expenditure is disaggregated](#)

738 into categories, however, several components exhibit sizeable and statistically significant
 739 treatment effects.

740 **Table 3.** DiD results for total household expenditure

Variable	Estimate
MMI group:Low × Post	3414.443413.71 (2322.802507.03)
MMI group:High × Post	1831.582010.89 (1399.871469.80)
Age of reference person	-237.911170.95*** (21.40100.93)
Age ²	-13.32*** (0.97)
Sex of reference person	-3388.78*** (768.82)
Household size	3105.636805.15*** (193.57594.64)
Observations: 5,025022	
*** p<0.01, ** p<0.05, * p<0.1	
* p<0.05, ** p<0.01, *** p<0.001	

741
 742 Certain expenditure categories, such as receipts and refunds, exhibit highly skewed distributions.
 743 For receipts and refunds, for example, roughly 90% a large share of observations are zero, and
 744 the remaining positive or negative values are concentrated in a heavy right-tail. Estimating
 745 ordinary least squares (OLS) regressions directly on these raw levels forces the model to fit a
 746 small number of very large observations, allowing them to exert disproportionate influence on
 747 the estimated coefficients.

748 To address these distributional features and improve interpretability, we estimate the category-
 749 level regressions using a log transformation of the absolute value plus one of each expenditure
 750 variable, that is, $\log(1+|y|)$. This transformation substantially stabilises the regression estimates
 751 and yields coefficients that capture relative differences in the magnitude of expenditure rather
 752 than being driven by a few extreme observations. For example, after this transformation, the
 753 coefficient for receipts and refunds in the high-intensity treatment group is 0.718729, implying
 754 that the magnitude of receipts and refunds (plus one) in the treatment group is approximately
 755 2.0507 times ($e^{0.718729}$) that in the control group, equivalent to an increase of about 107.2%.

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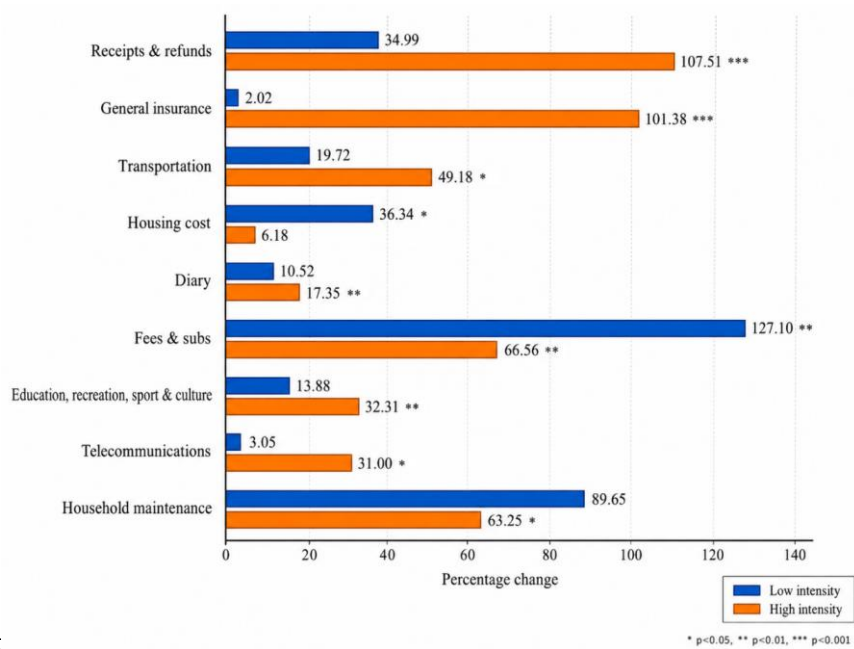
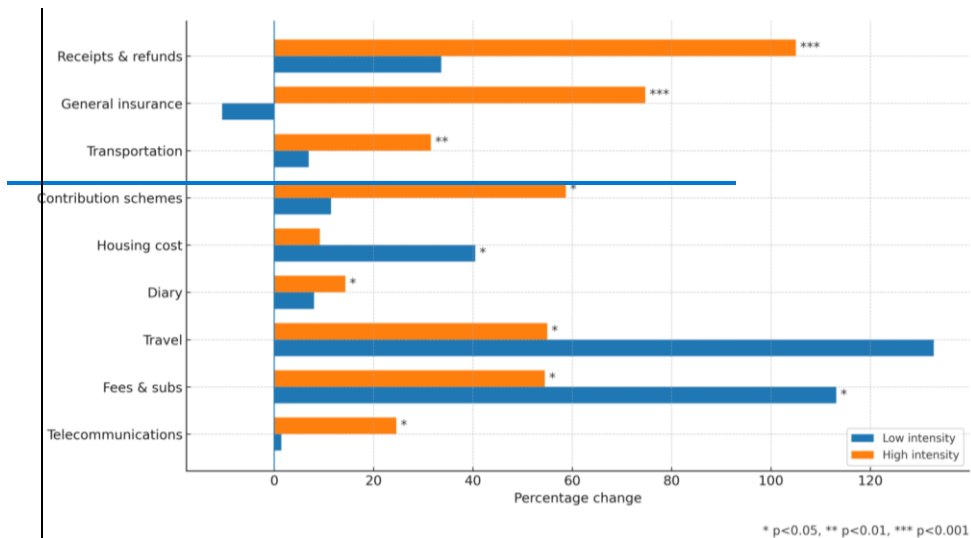
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75:

758 **Figure 2.** Post-earthquake changes in expenditure categories by [EQearthquake](#) intensity

As shown in Figure 2-~~6~~, with full regression estimates reported in Appendix E~~7~~, several expenditure categories exhibit statistically significant responses to the earthquakes, particularly among households in high-intensity areas.~~—~~

Households in high-intensity areas show a large and statistically significant increase in receipts- and refunds-related entries following the earthquakes. As noted above, this category also captures insurance reimbursements, which are recorded as negative expenditure items rather than income to avoid double-counting with other income sources such as wages or transfer payments (Stats NZ, 2020). The estimated log coefficient for the high-intensity group is 0.718, ~~implying that the~~ ~~729~~, corresponding to an increase of about 107.2% in the magnitude of receipts and refunds (plus one) ~~is approximately 2.05 times ($e^{0.718}$) that in the control areas.~~ This pattern ~~likely reflects—is consistent with~~ increased insurance claims ~~and related reimbursement flows~~ after the disaster. ~~Higher refund activity may~~The corresponding estimate for the low-intensity ~~group is also be consistent with more cautious consumption behaviour, as households may have been more inclined to return purchases or liquidate assets in response to heightened uncertainty~~positive, but it is not statistically significant.

~~Compared with the control group, the 'diary'~~General insurance expenditure ~~category~~ also increases ~~by around 14.3%substantially~~ in high-intensity areas~~—~~. The estimated coefficient = 0.134, $p < 0.05$). This ~~implies an increase of approximately 101.4%, and the~~ effect is statistically significant ~~and economically meaningful, especially given that the diary category primarily captures essential household expenditures, such as food, beverages and personal care, that typically exhibit low elasticity to income changes and limited responsiveness to external shocks~~at the 0.1% level. This pattern is consistent with increased insurance-related activity after the earthquakes, including changes in premiums, policy adjustments, or greater engagement with insurance products following heightened risk salience. Because the category captures expenditure on insurance rather than claim receipts, it should be interpreted separately from the receipts-and-refunds category.

~~Because the diary module records transactions in real time and is less susceptible to recall bias or privacy related underreporting, the resulting data are generally of high quality. It is therefore~~

~~notable that the estimated treatment effect for diary expenditure is both large and precisely estimated.~~

Compared with the control group, the diary-recorded day-to-day expenditure category increases by around 17.0% in high-intensity areas, and the estimate is statistically significant at the 1% level. This category captures small and frequently purchased items recorded through the HES expenditure diary. The increase may reflect higher routine living costs, immediate replacement needs, or changes in day-to-day consumption in the aftermath of the earthquakes. Because the diary module records transactions close to the time of purchase, it is less vulnerable to long recall periods than retrospective expenditure questions, although it may still be sensitive to short reporting windows.

~~Transportation, and telecommunications and travel all show statistically significant increases expenditure also increase significantly in high-intensity areas. Households may have incurred substantial~~Transportation expenditure rises by approximately 49.2%, while telecommunications expenditure increases by approximately 31.0%; both estimates are statistically significant at the 5% level. These patterns are consistent with additional costs related to vehicle repairs, mobility and replacements following the earthquakes. The observed rise in travel expenditure may be associated with additional trips taken to avoid communication needs after the disaster-affected areas, visit relatives or manage post earthquake uncertainty.

~~Both the low-, including commuting disruptions, vehicle-related expenses, and high-intensity groups exhibit increases in fees~~coordination with family members, insurers, repair providers, and public agencies.

~~Fees-and-subscriptions expenditure, with increases significantly in both low- and high-intensity areas. The estimated increase is approximately 127.1% in the low-intensity group and 66.5% in the high-intensity group showing a, with both estimates statistically significant rise at the 1% level.~~According to the HES classification, this category includes payments for club memberships, professional association fees, subscriptions to recreational or educational programmes, and other recurring service fees. The observed increase suggests that, rather than cutting back on, households did not uniformly reduce discretionary items, or subscription-based

815 spending after the earthquakes. Instead, some households may have maintained or even
816 expanded their engagement with subscription-based spending on services in the aftermath of the
817 earthquakes. This may reflect a desire for that provided continuity, social/professional connection
818 and access to structured recreational, education, recreation or educational activities/social
819 engagement during the recovery period of post-disaster uncertainty and dislocation.

820 Expenditure on social security and retirement contribution schemes increases significantly after
821 the earthquakes. According to the HES definition, this category primarily includes Accident
822 Compensation Corporation (ACC) contributions, KiwiSaver retirement savings contributions,
823 private superannuation scheme contributions, other pension and retirement fund contributions
824 and other social insurance scheme contributions. This pattern is consistent with macroeconomic
825 and microeconomic evidence that heightened uncertainty associated with exposure to large
826 shocks fosters precautionary saving: households continue to invest in social protection and long-
827 term retirement planning rather than reducing such payments (e.g., Aizenman & Noy, 2015). It
828 also suggests sustained trust in, and reliance on, institutional mechanisms for long-term risk
829 management among New Zealand households.

830 Unexpectedly, it is the low-intensity group, not rather than the high-intensity group, that
831 experiences a statistically significant increase in housing related expenditure (around 40.5%;
832 coefficient = 0.340, $p < 0.05$). This costs. The estimated increase is approximately 36.3% for
833 the low-intensity group and is statistically significant at the 5% level, whereas the high-intensity
834 estimate, approximately 6.2%, is not statistically significant. This pattern may reflect moderate
835 disruption even—in less severely affected areas, including repairs, temporary
836 relocations/accommodation, or upward pressure on rents in neighbouring areas due to population
837 displacement from harder-hit areas where many houses were no longer suitable for
838 occupation/locations. The absence of a statistically significant changes housing-cost response in
839 the high-intensity group may be due to reflect more severe housing damage, with that delayed
840 reconstruction delayed, insurance-managed repairs, or financed expenditure being recorded
841 through institutional channels rather than directly through insurance (through the public insurer's
842 Managed Repair programme) and thus not immediately captured in as household outlays.

Expenditure on education, recreation, sport and culture also increases in high-intensity areas. The estimated increase is approximately 32.3% and is statistically significant at the 1% level. Household-maintenance expenditure ~~records~~ rises by approximately 63.2% in the high-intensity group and is statistically significant at the 5% level. These results are consistent with households facing additional repair and maintenance needs while also maintaining or adjusting expenditure on educational, recreational, and cultural activities during the recovery period. The corresponding low-intensity estimates are positive but statistically insignificant.

Taken together, the expenditure results suggest that the Canterbury earthquakes did not generate a clear average increase in total household expenditure, but they did change the composition of spending. Statistically significant category-level responses are concentrated in receipts and refunds, general insurance, diary-recorded purchases, transportation, telecommunications, fees and subscriptions, education, recreation, sport and culture, household maintenance, and housing costs in low-intensity areas. This pattern is consistent with households adjusting along several margins after the disaster, including insurance and reimbursement flows, routine living expenses, mobility and communication needs, housing and maintenance costs, and subscription- and service-related expenditure.

As shown in Appendix F, a comparison of census data across New Zealand's 16 regions between 2006 and 2013 indicates that ~~Canterbury's compound~~ Canterbury recorded the second-highest annual growth rate and the second-largest absolute increase in median household income ~~reached 4.46%, ranking second, in both cases behind only to the West Coast (5.5%) and third in absolute median income growth behind Auckland and Wellington (Stats NZ, 2014).~~ This growth rate is substantially higher than in most other regions, suggesting that Canterbury's post-2006 income growth was relatively strong in the post-earthquake period, potentially reflecting reconstruction and recovery alongside other regional factors. This broader regional context is consistent with the income results reported in Section 5.1, while the expenditure results in this section indicate that increased income did not translate into a uniform increase in total household expenditure, but rather into category-specific adjustments.

5.3 Heterogeneous effects by income group

871 As shown in Figure 3 and ~~Table G1, G2~~Tables G.1 and G.2 in Appendix G, ~~among~~
872 ~~expenditure responses differ substantially between households above and below the~~
873 ~~median income. Among~~ households with income above the median, post-earthquake
874 ~~increases in expenditure remain~~adjustments are broad ~~but exhibit some notable shifts in~~
875 ~~statistical significance~~and appear across several categories. The regression results indicate
876 ~~that high income households experienced~~statistically significant increases in ~~spending on~~
877 ~~contribution schemes~~housing costs, receipts and refunds, general insurance, miscellaneous
878 ~~payments,~~ telecommunications, ~~general insurance, transportation and travel. In particular, the~~
879 ~~substantial rise in fees and subscriptions, and~~ household maintenance ~~and general~~in at least
880 ~~one of the two intensity groups. Although travel expenditure is not statistically~~
881 ~~significant in the full-sample category regression, a significant increase appears among~~
882 ~~below-median-income households in the low-intensity group. These patterns suggest~~
883 ~~that above-median-income households adjusted along multiple margins, including~~
884 ~~insurance expenditure suggests related activity, housing and maintenance expenditure,~~
885 ~~communication needs, and discretionary or subscription-based spending.~~
886 ~~For above-median-income households, receipts and refunds increase markedly,~~
887 ~~especially in high-intensity areas. The estimated coefficient for the high-intensity group~~
888 ~~is 1.04, corresponding to an increase of approximately 182.9% in the magnitude of~~
889 ~~receipts and refunds plus one. The low-intensity coefficient is also positive,~~
890 ~~corresponding to an increase of about 76.8%, although it is not statistically significant.~~
891 ~~This pattern is consistent with the interpretation that higher-income households were~~
892 ~~more actively engaged in mobility, risk management and longer-term repair or relocation~~
893 ~~activities following the disaster.~~
894 ~~This pattern is consistent with~~likely to receive larger insurance reimbursements, refunds,
895 ~~proceeds from second-hand sales, or other compensatory inflows after the earthquakes.~~
896 ~~It also aligns with~~ international evidence that post-disaster reconstruction
897 ~~activities~~activity and insurance payouts ~~tend to often~~ benefit middle- and high-income
898 households more, ~~as they because these households~~ are better positioned to finance
899 reconstruction and ~~to~~make effective use of incoming funds (Kousky, 2014).~~The~~

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General insurance expenditure also rises sharply among above-median-income households in high-intensity areas. The estimated coefficient of 0.89 implies an increase of approximately 143.5%, and the effect is statistically significant. This increase should be interpreted separately from receipts and refunds: while receipts and refunds include insurance reimbursements and related inflows, the general-insurance category captures expenditure on insurance products. The combination of increased receipts and refunds and increased general-insurance expenditure suggests a broader intensification of insurance-related financial activity among higher-income households following the earthquakes.

Fees and subscriptions also show large statistically significant increases among above-median-income households. The estimated increase is particularly large in the low-intensity group, where the coefficient of 1.31 corresponds to an increase of approximately 270.6%. The high-intensity coefficient is also positive and statistically significant, corresponding to an increase of about 82.2%. The observed increase suggests that higher-income households did not uniformly reduce discretionary or subscription-based spending after the earthquakes. Instead, some households may have maintained or expanded spending on services that provided professional connection, continuity, recreation, education, or social engagement during the recovery period.

Above-median-income households also show significant increases in ~~contribution~~ schemes further indicate that these households continued to invest in institutional protection mechanisms, such as retirement savings and social insurance, in the face of increased salience of disaster-related uncertainty. telecommunications expenditure in both low- and high-intensity areas. The estimated increases are approximately 47.7% for the low-intensity group and 35.0% for the high-intensity group. This pattern is consistent with greater communication and coordination needs after the disaster, including contact with insurers, contractors, employers, family members, and public agencies.

~~Receipts and refunds~~ Housing costs also increase markedly for high income households significantly in both intensity groups. The estimates imply that, in the post-disaster period, these households receive larger amounts of refunds, proceeds from second hand

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929 sales and insurance reimbursements than in earlier periods. This pattern likely reflects the lagged
930 nature of certain compensatory inflows, such as insurance settlements or asset liquidations,
931 which may continue to generate cash inflows beyond the immediate aftermath of the disaster as
932 claims are processed and households adjust their asset portfolios.

933 Among high income households in increases of approximately 32.3% in the low-intensity
934 group, fees and subscriptions also rise sharply: the coefficient is 1.17 ($p < 0.05$), corresponding
935 to a very large proportional increase of about 222.8% in the magnitude of fees and subscriptions
936 relative to the control and 15.0% in the high-intensity group. This suggests that higher-
937 income households maintained, or gradually resumed, discretionary spending on memberships
938 and subscriptions during the post-disaster period.

939 For low income households, post-earthquake expenditure adjustments are Household-
940 maintenance expenditure exhibits a different pattern. The estimated increase is
941 approximately 127.1% in the low-intensity group, but this estimate is not statistically
942 significant in only a small number of categories, predominantly those covering essential goods
943 and services. The notable increase in diary. In the high-intensity group, household-
944 maintenance expenditure (about 15.5%; coefficient = 0.144, $p < 0.05$) underscores this pattern,
945 as the diary category encompasses routine, inelastic expenses such as food, beverages and
946 personal care. The concentration of increases by approximately 166.4% and is statistically
947 significant changes in these fundamental consumption items suggests that lower-income
948 households faced tighter financial constraints that limited their ability to adjust discretionary
949 spending. Observed expenditure shifts primarily take the form of modest increases in basic
950 necessities, likely driven by immediate post-disaster needs or inflationary pressure on essential
951 goods, rather than deliberate reallocation across broader consumption categories at the 1% level.
952 These findings are consistent with housing-related adjustment, repair, maintenance, and
953 accommodation costs playing an important role in higher-income households' post-
954 disaster expenditure responses.

955 Miscellaneous payments also increase significantly for above-median-income
956 households in high-intensity areas, with an estimated increase of approximately 95.4%.
957 Given the broad nature of this category, the result should be interpreted cautiously.

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958 However, it is consistent with the broader pattern that higher-income households
 959 adjusted across a relatively wide set of expenditure categories after the earthquakes.

960 For households with income below the median, post-earthquake expenditure adjustments
 961 are more concentrated. Significant increases appear in receipts and refunds, medical and
 962 health expenditure, diary-recorded day-to-day purchases, and travel. In high-intensity
 963 areas, receipts and refunds increase by approximately 40.5%, medical and health
 964 expenditure increases by approximately 41.9%, and diary-recorded purchases increase
 965 by approximately 18.5%. These categories are more closely related to immediate
 966 liquidity, health needs, and routine household consumption than to broader discretionary
 967 or asset-related adjustment. This pattern suggests that lower-income households' post-
 968 disaster expenditure responses were more focused on essential or near-essential needs.

969 The increase in diary-recorded day-to-day purchases among below-median-income
 970 households is particularly relevant because the diary category captures routine,
 971 frequently purchased items such as food, beverages and personal care. The estimated
 972 high-intensity effect of 0.17 corresponds to an increase of approximately 18.5%. This
 973 finding is consistent with lower-income households facing higher routine living costs or
 974 immediate replacement needs after the earthquakes, while having more limited capacity
 975 to adjust across wider expenditure categories.

976 Receipts and refunds also increase significantly for lowbelow-median-income
 977 households in high-intensity areas (about 34.6%; coefficient = 0.297, $p < 0.05$), largely
 978 reflecting. The estimated increase of approximately 40.5% suggests that lower-income
 979 households also received post-disaster cash reimbursements or related inflows—most
 980 likely as insurance reimbursements. Given New Zealand's atypical and near-universal
 981 household insurance coverage, even low income households in severely affected areas benefited
 982 from claims settlements, leading to observable increases in this category. However, the
 983 magnitude of this effect is considerably is much smaller than for high-the corresponding
 984 increase for above-median-income households, for whom the estimated increase is around
 985 188.64% (coefficient = 1.06); high-intensity estimate is approximately 182.9%. This gap
 986 likely reflects is consistent with differences in asset ownership, insurance depth, and asset

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987 ~~portfolios: higher~~the value of insurable possessions. Higher-income households typically
 988 own more ~~insurable~~valuable assets and ~~higher-value possessions~~have greater capacity to
 989 ~~engage with insurance and repair processes,~~ generating larger claim amounts and
 990 subsequent ~~refunds, whereas lower income households, despite similar insurance coverage~~
 991 ~~rates on paper, insure fewer high-value items, limiting the scale of post-disaster compensatory~~
 992 ~~inflows (Owen & Noy, 2019).~~reimbursements. Thus, while receipts and refunds provide
 993 ~~important~~ liquidity relief across income groups, the ~~disparity~~difference in effect size
 994 ~~underscores~~points to underlying wealth and asset inequalities in recovery capacity. (Owen
 995 ~~& Noy, 2019).~~
 996 Medical and health expenditure also increases significantly for below-median-income
 997 households in high-intensity areas. The estimated increase of approximately 41.9%
 998 suggests that lower-income households may have faced greater health-related needs or
 999 out-of-pocket health costs after the earthquakes. This result is consistent with the broader
 1000 literature showing that disasters can impose substantial non-property costs on vulnerable
 1001 households, including health, stress, and disruption-related expenses.
 1002 One notable result for below-median-income households is the large increase in travel
 1003 expenditure in the low-intensity group. The estimated coefficient of 1.19 corresponds to
 1004 an increase of approximately 228.7%. Because travel expenditure can be highly skewed
 1005 and episodic, this result should be interpreted cautiously. Nevertheless, it may reflect
 1006 temporary relocation, visits to relatives, travel to avoid disrupted areas, or other mobility
 1007 needs following the earthquakes. The fact that this effect appears in the low-intensity
 1008 group rather than the high-intensity group suggests that travel responses may not follow
 1009 a simple monotonic relationship with local shaking intensity.
 1010 The relatively ~~narrow~~narrower range of significant spending increases among ~~low~~below-
 1011 median-income households ~~more broadly reflects their~~is consistent with constrained post-
 1012 disaster financial capacity. Compared with higher-income households, ~~low~~lower-income
 1013 households tend to have less access to savings, credit, insurance, ~~social protection,~~ and
 1014 informal financial support, which limits their ability to ~~absorb disaster losses and~~ adjust
 1015 expenditures beyond ~~essential~~immediate needs (Deryugina, 2017; ~~Hickel & Hallegatte,~~

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2022). et al., 2020). The results therefore suggest that lower-income households respond to the earthquakes mainly through liquidity-related inflows, routine purchases, health-related spending, and selected mobility costs, rather than through broad-based discretionary, insurance, or housing-maintenance adjustments,

Taken together, these findings highlight the heterogeneous nature of household financial responses to disasters. HighAbove-median-income households exhibit broad-based post-disaster adjustments in several expenditure across insurance, housing, maintenance, communications, and subscription-related categories, whereas low. Below-median-income households respond more narrowly, with targeted changes in more core spending categories—significant changes concentrated in receipts and refunds, medical and health expenditure, diary-recorded purchases, and travel. This divergence reinforces the central role of income and financial capacity in shaping differential post-disaster expenditure dynamics and is consistent with the emergingbroader literature on disaster-related inequality (Dube and socioeconomic resilience (Roth, Tran & Wilson, 2023; Hiekel & 2025; Hallegatte, 2022 et al., 2020).

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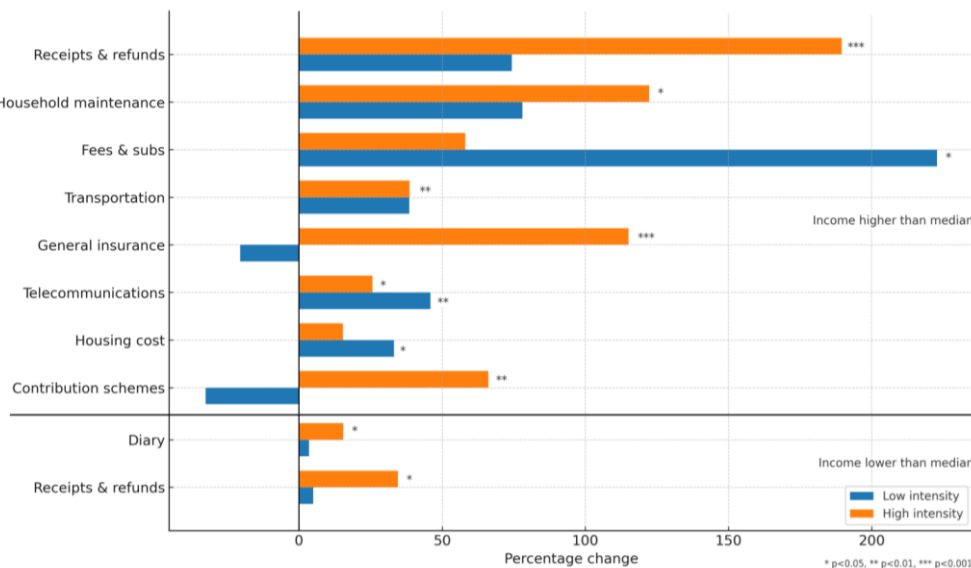
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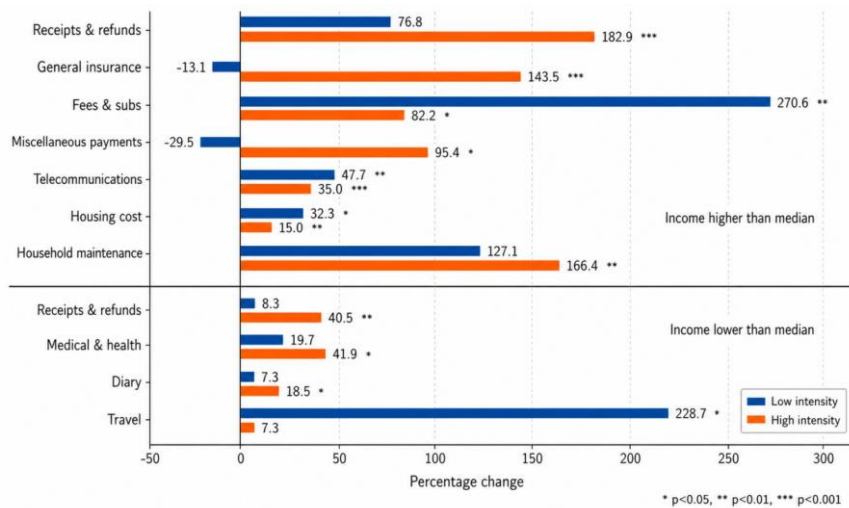
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1035 **Figure 3.** Post-earthquake changes in expenditure by income group

1036 5.4 Heterogeneous effects of migration

1037 To assess the heterogeneous effects ~~of~~associated with post-earthquake migration, we compare
 1038 households that remained in Canterbury ("stay" households) with those that relocated out of the
 1039 region ("relocation" households) ~~across five~~within the treated sample. We examine six key
 1040 economic indicators: total household income, total regular household income, total household
 1041 expenditure, housing costs, ~~other property expenditure~~, and mortgages and loans. These five
 1042 variables ~~are consistently available in each HES wave~~capture income, overall spending, and ~~thus~~
 1043 ~~allow for a balanced comparison over time~~housing-related financial commitments. We estimate
 1044 separate linear regressions for each outcome, including a dummy variable for relocation
 1045 households, and control for the age of the reference person, ~~the sex of the reference person~~, and
 1046 household size. The regression results are reported in Table 4.

1047 **Table 4.** Covariate-adjusted differences between stay and relocation households (descriptive)

	Total income	Regular income	Total expenditure	Housing cost	other property	Mortgage
	56036.3461,677.26***	53813.6559,522.58***	25027.0824,994.55***	39004.2839,211.64***	17853.49**	21.20
	(6602,266,818.50)	(6055,576,251.13)	(4567,711,623.00)	(5752,675,953.41)	1,008.71	(5.65)
427.33	1,005.00	664.48	24,901.31***	-606.05	-9,585.52*	
indicator-						
group, 0 =	754.24(5,112.98)	4331.34(4,687.53)	672.64(1,217.04)	24967.88***(-4,464.28)	-	4.24
					9466.120*(488.50)	(4.46)
	234.00**	-226.48**	(5124,258.44)**	(4700.12)-668.64***	(1216.80)23.39**	386.8
age	-235.68**	-227.56**	-259.79***	-676.11***	-377.65***	
	(87.0706)	(79.8682)	(20.6872)	(75.8776.02)	(8.31)	(72.4)
	-11,136.70***	-254.33	-2,137.92	-445.32	-4,243.34	
	11,127.09***					
(2,731.56)	(2,504.27)	(650.19)	(2,385.00)	(260.87)	(2,266.48)	
	7879.3418,204.61***	17,665.86***	2,584.06***	17359,14,427.12***	2536.17397.67***	1414
	(1144,841,154.96)	(4050,041,058.85)	(271,84274.91)	(997,521,008.42)	(948,16110.30)	(958)
observations	5463,546	35463,546	3546,3,546	35463,546	35463,546	3,546

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pensions, and fixed transfer payments, there is no statistically detectable gap between ~~relocated~~relocation and stay households. This further ~~supports the interpretation~~suggests that relocation is not primarily associated with a conditional difference in regular income. Instead, migration decisions ~~primarily are more likely to~~ reflect residential, housing, family, or ~~disruption-related~~ coping strategies in response to the disaster, rather than ~~deliberate income-maximising strategies~~ differences alone.

The coefficient on total household expenditure is also positive but not statistically significant. This indicates that, after controlling for age, sex, and household size, relocation households do not exhibit a clear difference in overall expenditure relative to stay households. This result is consistent with the broader expenditure findings in Section 5.2, where total expenditure does not show a statistically significant average DiD effect, even though several expenditure categories respond strongly.

By contrast, more pronounced heterogeneity emerges when focusing on housing-related expenditure. For housing costs, relocation households exhibit ~~significantly-substantially~~ higher spending than stay households, with an estimated coefficient of NZD 24,967 (standard error = 4,465, $p < .001$ and statistical significance at the 0.001)-1% level. This indicates that households ~~who moved out of~~observed outside Canterbury after the earthquakes faced ~~substantially greater~~much higher housing-related costs ~~after the earthquakes, potentially due to, conditional on basic household characteristics. This pattern is consistent with relocation involving higher rents in destination areas and upfront expenses associated with securing new, temporary accommodation, such as relocation costs, rental bonds and agency fees. These findings reflect the direct impact of the earthquakes on, or other costs associated with securing new housing markets and on the cost structure of household accommodation for migrants~~after displacement.

Other property expenditure is lower among relocation households, but the coefficient is not statistically significant. Given the lack of statistical precision, this result should be interpreted cautiously and should not be treated as evidence of a systematic difference between relocation and stay households. It nevertheless points in the same broad direction as the mortgages-and-loans result, suggesting that households that left Canterbury may have been less tied to property-related financial commitments than those that remained.

For mortgages and loans, ~~by contrast,~~ the relocation group shows significantly lower expenditure than the stay group, ~~with an~~. The estimated coefficient ~~of~~ is approximately NZD -9,466 (standard error = 4,244, $p < 0.05$), 586 and is statistically significant at the 5% level. This suggests that relocated households were ~~more likely to rent rather than purchase new homes, thereby avoiding new long-term debt obligations and less likely to carry large mortgage commitments. In contrast, households that remained in place were more inclined to retain ownership of their original properties or invest in the reconstruction of damaged homes, resulting in higher~~ or loan burdens.

~~It is noteworthy that across all five models, the age of the household reference person and household size are consistently highly significant (all $p < 0.01$). In our specification, age enters the regression linearly, so the estimates capture only the average slope across the observed age distribution. The negative coefficients~~ payments than households that remained in Canterbury, conditional on age ~~suggest that, conditional on~~, sex, and household size ~~and migration status, households with older reference persons tend to have somewhat lower income and expenditure levels on average. This pattern is consistent with the downward sloping portion of the life-cycle profile (Modigliani, 1986). However, we cannot recover the earlier increasing phase, typically peaking in middle age, because the model does not include non-linear terms such as age squared. A robustness check with quadratic age terms would be~~. One plausible interpretation is that stay households were more likely to retain owner-occupied properties, continue mortgage repayments, or finance repair and reconstruction, whereas relocation households were more likely to move into rental or temporary accommodation and avoid new long-term housing debt.

~~The control variables also behave largely as expected to reveal the familiar inverted U shape, but in the current linear specification the dominant relationship is the declining trend at older ages.~~

~~By contrast, the positive and sizable coefficients on household~~ Household size indicate that, holding age and migration status constant, is positive and highly significant across all six outcomes, indicating that larger households tend to have higher income and greater total expenditure levels, which is consistent with the presence of multiple earners, and greater consumption needs. The larger housing-related financial commitments. This pattern is consistent with theoretical expectations regarding household scale effects in household: as households grow

in size, they typically include more potential earners and face greater aggregate consumption needs, ~~leading to higher total income and expenditure~~ (Browning et al., 2013). ~~Age is negatively associated with income, total expenditure, housing costs, and mortgages and loans, but positively associated with other property expenditure. This pattern is broadly consistent with life-cycle variation in income, expenditure, and asset-related commitments (Modigliani, 1986), although the linear age specification should be interpreted as an average association over the observed age distribution rather than as a full life-cycle profile.~~

In summary, although migration is self-selected and the estimated differences cannot be interpreted as causal effects of relocation, the data reveal clear and systematic contrasts in housing-related ~~costs~~ expenditure between relocated and non-relocated households. Relocation households ~~exhibit substantially higher rental expenses and one off housing payments, alongside do not differ significantly lower long term mortgage and loan expenditures, compared with~~ from stay households ~~that remained in place. These~~ total income, regular income, or total expenditure after adjustment. The main differences ~~likely reflect pre-existing disparities~~ are instead concentrated in housing ~~tenure, financial circumstances and other unobserved characteristics that jointly shape both migration decisions and housing expenditure patterns~~ costs and mortgages and loans: relocation households face substantially higher housing costs, while stay households appear to carry higher mortgage and loan payments.

This shift in expenditure structure underscores the considerable heterogeneity in housing consumption and asset-investment decisions following ~~disaster induced migration. It also reinforces the plausibility of the treated group definition and the robustness of the heterogeneity analysis employed in this study, while providing important insight into post disaster housing markets and household financial decision making~~ post-disaster migration. It is also consistent with international evidence that post-disaster migration is selective, with younger, more mobile, and less housing-secure households more likely to move after major disasters (Fussell, 2015). These results reinforce the importance of distinguishing between income effects and housing-cost effects when evaluating household recovery after disasters. They also provide useful evidence that post-earthquake migration was closely related to the structure of household housing costs and housing-related financial commitments, even though average income

differences between movers and stayers are limited once observable characteristics are taken into account.

5.5 Robustness check

Table 5. Robustness checks for total household income

	Origin Baseline	Caliper = 0.1	Ratio = 1:1	Remove "sex"
MMI group: Low × Post	4799.547043.47* (3022.602889.43)	5098.347686.24* (3010.532943.46)	4775.338088.52* (3504.743348.37)	3920.067736.2* (3003.322939.97)
MMI group: High × Post	7626.427251.79* (3444.073559.44)	7942.887841.80* (3375.993695.82)	7642.978265.12* (3493.273508.18)	6839.827888.46* (3885.103759.87)
Observations	1720217193	1690217166	1128011457	1692617190

* p < 0.05, ** p < 0.01, *** p < 0.001

Table 6. Robustness check for total household regular income

	Origin Baseline	Caliper = 0.1	Ratio = 1:1	Remove "sex"
MMI group: Low × Post	5277.877924.42** (2878.502673.83)	5577.698408.67** (2877.632719.98)	5887.259345.04** (3402.983159.44)	4198.688491.58** (2924.622734.90)
MMI group: High × Post	7426.387411.86* (3333.843286.86)	7747.907862.88* (3246.883453.67)	8068.118821.37* (3482.683397.87)	6420.087941.48* (3757.123538.41)
Observations	1720217193	1690217166	1128011457	1692617190

* p < 0.05, ** p < 0.01, *** p < 0.001

Table 7. Robustness check for total household expenditure

	Origin Baseline	Caliper = 0.1	Ratio = 1:1	Remove "sex"
MMI group: Low × Post	3414.143413.71 (2322.802507.03)	2522.2525.22 (2282.562432.83)	2375.702340.68 (2661.572836.63)	2967.912984.43 (2256.222433.38)
MMI group: High × Post	1831.582010.89 (1399.871469.80)	1098.991310.34 (1319.691326.58)	847.771019.43 (1837.961897.99)	1517.951715.47 (1292.401329.31)
Observations	50255022	5016	3354	5025

* p < 0.05, ** p < 0.01, *** p < 0.001

To ensure the reliability of the estimated post-earthquake effects on household income and expenditure, we conduct a series of robustness checks using alternative PSM specifications. The original model employs nearest-neighbour matching with a caliper of 0.2, a 1:2 matching ratio, a logit-based propensity score and four matching covariates: age of the reference person, household size, sex and education. We then alter one dimension at a time and re-estimate the DiD models. The results are summarised in Tables 5 – 7.

Using a stricter caliper ~~(, reducing the maximum propensity-score distance from 0.2 to 0.1),~~ yields estimates that are very similar to the baseline results. For total household income, the estimated post-earthquake effects remain positive and statistically significant for both the low- and high-intensity groups. The coefficients are slightly larger estimated effects than in the baseline specification, increasing from around NZD 7,043 to NZD 7,686 for the low-intensity treatment group and marginally smaller p-values. This indicates that the main results remain robust even when matching is restricted to closer neighbours from around NZD 7,252 to NZD 7,842 for the high-intensity group. The corresponding estimates for regular household income are also slightly larger and remain statistically significant. These results indicate that the income findings are not driven by relatively distant matches in the propensity-score space.–

When we reduce the matching ratio ~~to 1:1 (instead of from 1:2), the estimated treatment effects become~~ to 1:1, the income estimates again remain positive and statistically significant. The point estimates are somewhat larger ~~in magnitude and standard errors increase slightly. The same effects nevertheless remain economically meaningful and statistically significant at conventional levels, suggesting that the results are not driven by~~ than in the baseline specification: for total household income, the low- and high-intensity coefficients increase to around NZD 8,089 and NZD 8,265, respectively; for regular household income, they increase to around NZD 9,345 and NZD 8,821. The number of observations is smaller under 1:1 matching, as expected, because only one matched control household is retained for each treated household. The persistence of positive and statistically significant income effects under this more restrictive matching design suggests that the income results are not sensitive to the choice of matching ratio.

We next exclude the reference person's sex from the set of matching covariates. Removing sex has only a modest impact on the estimated income effects. The low- and high-intensity coefficients: ~~the direction and magnitude of the treatment effects~~ remain stable, while statistical significance ~~declines slightly, consistent with a small reduction~~ positive and statistically significant for both total household income and regular household income, and their magnitudes are close to those in the baseline model. This suggests that the main income results are not driven by the inclusion of sex in the propensity-score matching ~~precision after omitting~~ procedure.

The robustness checks for total household expenditure show a different but consistent pattern. Across all specifications, the estimated expenditure effects remain positive but statistically insignificant for both the low- and high-intensity groups. Under the stricter caliper, the coefficients decline to around NZD 2,525 for the low-intensity group and around NZD 1,310 for the high-intensity group. Under 1:1 matching, they are smaller still, at around NZD 2,341 and NZD 1,019, respectively. When sex is removed from the matching covariates, the estimates remain positive but imprecise. These results reinforce the conclusion from Section 5.2 that the earthquakes did not generate a ~~potentially informative covariate~~. statistically clear average increase in total household expenditure, even though several expenditure categories changed substantially.

Lastly, we replace the logit model with a probit specification when estimating the propensity scores³. The resulting DiD estimates are nearly identical to the baseline, indicating that the matched-sample results are robust to the choice of link function in the propensity-score model. We also re-estimate the models using propensity scores derived from a linear probability model (LPM) instead of a logit specification. Diagnostic statistics, such as the maximum standardised mean difference and variance ratios, indicate that the LPM-based matching procedure achieves

³ We also re-estimate the models using propensity scores derived from a linear probability model (LPM) instead of a logit specification. Diagnostic statistics, such as the maximum standardised mean difference and variance ratios, indicate that the LPM-based matching procedure achieves covariate balance that is comparable to that of the baseline logit-based matching. However, the estimated treatment effects obtained from the LPM-based propensity scores are smaller in magnitude and generally less statistically significant than those based on logit or probit models. This pattern is consistent with existing methodological evidence. Austin (2011b) shows that matching on the logit of the propensity score with a caliper of 0.2 standard deviations tends to yield substantial bias reduction and efficiency gains, whereas alternative specifications perform less well. Thus, while balance metrics look similar on average, the attenuated coefficients and reduced significance under the LPM specification likely reflect its weaker ability to distinguish units at the extremes of the treatment probability distribution, leading to marginally poorer matches and larger standard errors near the boundaries.

covariate balance that is comparable to that of the baseline logit-based matching. However, the estimated treatment effects obtained from the LPM-based propensity scores are smaller in magnitude and generally less statistically significant than those based on logit or probit models. This pattern is consistent with existing methodological evidence. Austin (2011b) shows that matching on the logit of the propensity score with a caliper of 0.2 standard deviations tends to yield substantial bias reduction and efficiency gains, whereas alternative specifications perform less well. Thus, while balance metrics look similar on average, the attenuated coefficients and reduced significance under the LPM specification likely reflect its weaker ability to distinguish units at the extremes of the treatment-probability distribution, leading to marginally poorer matches and larger standard errors near the boundaries.

We further conduct a series of additional checks in which each matching covariate is removed one at a time. The results are consistent with the patterns described above. Excluding any single covariate generally worsens covariate balance to some extent, as reflected in slightly higher standardised mean differences or variance ratios, but the estimated treatment coefficients remain directionally stable and their magnitudes are not materially altered.

We also conduct two additional sets of robustness checks, reported in Appendices H and I. First, we estimate a continuous-MMI specification to assess whether the results are sensitive to the discrete low/high intensity classification. The continuous-MMI interaction terms are not statistically significant, suggesting that the post-earthquake response does not follow a simple linear gradient in shaking intensity. This supports the use of the grouped intensity specification in the main analysis. Second, we compare the baseline specification with alternative age controls and ATT-IPW bridge specifications. The income effects remain positive across these checks, while the total-expenditure effects remain statistically imprecise, reinforcing the main interpretation.

Taken together, these robustness checks show that the ~~magnitude, direction and statistical significance of the estimated treatment effects are broadly consistent across a wide~~main conclusions are stable across a range of alternative matching specifications, ~~reinforcing the~~. The income effects remain positive and statistically significant across the stricter caliper, 1:1 matching, and the specification excluding sex from the matching covariates. The total-

expenditure estimates remain positive but statistically insignificant across the same checks. These patterns reinforce the credibility of our findings: the main interpretation: the Canterbury earthquakes are associated with increases in household income, while changes in expenditure are more visible in specific expenditure categories than in total household expenditure.

6. Conclusion and Discussion

This study systematically evaluates the medium- to longer-term impacts of the 2010–2011 Canterbury earthquakes on household income and expenditure. By linking nationally representative Household Economic Survey data to administrative address histories and meshblock-level earthquake-intensity measures within New Zealand's Integrated Data Infrastructure, we identify households that resided in Canterbury region. By combining a Difference-in-Differences econometric strategy at the time of the earthquakes and compare their outcomes with Propensity Score Matching, the those of contemporaneously matched North Island households. The analysis aims to strengthen both the causal interpretation and the treats the HES as a repeated cross-section and combines propensity-score matching with a difference-in-differences design, supplemented by event-study estimates, compositional-balance tests, alternative matching specifications, and an ATT-IPW robustness of the estimated effects. We provide a comprehensive assessment across multiple dimensions—total and household income and a wide range of expenditure categories.

6.1 Key findings

First, in terms of income effects, households in high-intensity earthquake areas experience a significant post-disaster increase in income, with estimates consistently statistically significant at conventional levels. This finding diverges from the traditional view that disasters primarily lead to income losses and instead aligns with more recent microeconomic work emphasising post-disaster economic recovery and inflows of financial resources (e.g., Deryugina, 2017). In particular, increased labour demand associated with reconstruction, together with inflows from insurance payouts and government assistance programmes, appear to jointly contribute to the observed rise in household income.

~~Second, for expenditure, aggregate changes in total household spending are not statistically significant. However, when expenditure is disaggregated by category, substantial heterogeneity emerges. The categories with significant post-earthquake increases are concentrated in transportation, travel.~~ The first main finding is that both total household income and regular household income increased in earthquake-exposed areas relative to the matched comparison group. For total household income, the estimated post-earthquake increases are approximately NZD 7,043 in low-intensity areas and NZD 7,252 in high-intensity areas. The corresponding estimates for regular household income are approximately NZD 7,924 and NZD 7,412. The similarity of the estimates across the two intensity groups suggests that the income response was not confined to the locations experiencing the most severe ground shaking.

The event-study evidence supports this interpretation. The pre-earthquake coefficients for the two income outcomes are individually imprecise, and joint Wald tests fail to reject the null hypothesis that they are jointly equal to zero. Post-earthquake coefficients become positive in several subsequent waves, with some of the largest estimates appearing during the later reconstruction period. These patterns are consistent with reconstruction-related labour demand, wage and employment effects, and broader regional recovery dynamics (Wood et al., 2016; Roth Tran & Wilson, 2025). The positive effects on regular income are particularly important because they indicate that the results are unlikely to be explained solely by one-off insurance settlements or compensation payments.

The income results should not, however, be interpreted as evidence that the earthquakes improved household welfare. Increased labour demand, insurance-related inflows, and public reconstruction expenditure may raise measured income while households simultaneously experience housing damage, disruption, displacement, health effects, and additional living costs. This distinction is central to the economic interpretation of disaster recovery: positive income growth after a disaster may reflect costly reconstruction and compensatory activity rather than a net welfare gain.

Second, total household expenditure does not exhibit a statistically significant average DiD effect. The estimated coefficients are positive for both the low- and high-intensity groups, but they are imprecisely estimated. This result is stable across alternative matching calipers.

1298 matching ratios, and covariate specifications. The event-study evidence for total expenditure is
1299 necessarily more limited because comparable full-expenditure information is available in only
1300 four HES waves, leaving only one comparable pre-earthquake coefficient. That coefficient is not
1301 statistically significant, but the limited pre-period means that the parallel-trends evidence for
1302 expenditure is weaker than for income.

1303 The absence of a clear effect on total expenditure masks substantial changes in expenditure
1304 composition. In high-intensity areas, the magnitude of receipts and refunds increases by
1305 approximately 108%, and general-insurance expenditure increases by approximately 101%.
1306 Significant increases also appear in transportation, telecommunications, diary-recorded day-to-
1307 day purchases, fees and subscriptions, education, recreation, sport and culture, and household
1308 maintenance. In low-intensity areas, housing costs and fees and subscriptions increase
1309 significantly. These findings indicate that households adjusted across several distinct margins,
1310 including insurance and reimbursement flows, routine consumption, mobility, communication,
1311 housing and maintenance, and subscription- and service-related spending.

1312 Receipts and refunds deserve particular attention. In the HES, this category includes insurance
1313 reimbursements and related inflows recorded as negative expenditure entries. The large high-
1314 intensity effect is therefore consistent with substantial post-earthquake insurance and
1315 compensation activity. At the same time, the category is broader than insurance settlements alone,
1316 and the use of $\log(1+|y|)$ means that the estimates capture changes in the magnitude of recorded
1317 entries rather than their direction as net cash inflows or outflows. The results should
1318 consequently be interpreted as evidence of increased insurance- and refund-related financial
1319 activity, rather than as a direct estimate of household compensation income.

1320 Third, expenditure responses differ markedly by household income. Above-median-income
1321 households exhibit significant adjustments across a relatively broad range of categories,
1322 including receipts and refunds, general insurance, housing costs, household maintenance,
1323 telecommunications, miscellaneous payments, and fees and subscriptions. In high-intensity areas,
1324 the estimated increase in the magnitude of receipts and refunds is approximately 183% for above-
1325 median-income households, compared with approximately 41% for below-median-income
1326 households. This gap is consistent with differences in asset ownership, insurance depth, claim

size, and households' capacity to engage with repair and compensation processes (Kousky, 2014; Owen & Noy, 2019).

Below-median-income households exhibit a narrower pattern of adjustment. Significant changes are concentrated in receipts and refunds, medical and health expenditure, diary-recorded day-to-day purchases, and travel. This pattern is consistent with more constrained households focusing their adjustments on liquidity, health, essential consumption, and selected mobility needs rather than on a broad set of discretionary, housing-maintenance, or asset-related categories. The results therefore suggest that income and asset ownership shape not only the scale of post-disaster adjustment but also the margins through which households are able to respond.

Fourth, the migration analysis identifies substantial differences in housing-related expenditure between households that remained in Canterbury and those later observed outside the region. Conditional on age, sex, and household size, relocation households do not differ significantly from stay households in total income, regular income, or total expenditure. They do, however, report housing costs approximately NZD 24,901 higher and mortgage-and-loan expenditure approximately NZD 9,586 lower.

These estimates are descriptive associations rather than causal effects of relocation. Migration was self-selected and was likely influenced by housing damage, tenure, employment, family circumstances, financial resources, and other unobserved characteristics. Nevertheless, the results indicate that post-earthquake mobility was closely associated with the structure of housing expenditure. Relocation households appear to have faced greater accommodation or resettlement costs, while households that remained were more likely to retain mortgage and loan commitments connected to existing properties, repairs, or reconstruction. This pattern is consistent with evidence that post-disaster migration is selective and that younger and less housing-secure households are generally more mobile after major shocks (Fussell, 2015).

The main conclusions are supported by a range of robustness checks. The income estimates remain positive under stricter propensity-score calipers, 1:1 matching, alternative matching covariates, and alternative age specifications. Pseudo-outcome tests provide no evidence of systematic differential changes in the principal demographic covariates or broad household-

composition categories. The continuous-MMI interactions are not statistically significant, suggesting that the response does not follow a simple linear gradient in ground-shaking intensity and that the grouped estimates may capture non-linear differences in household adjustment. ATT-IPW estimates generally preserve the direction of the income effects but are less precisely estimated when the full eligible control pool is used. The weighting results therefore support the substantive direction of the PSM findings while also indicating that statistical precision depends on the choice of comparison sample and estimator.

domestic fuel and power, household maintenance and repair, social insurance and retirement contributions, and medical and health-related expenses. These changes reflect a marked shift in household demand structures following the disaster, driven in part by compulsory cost increases related to vehicle repairs, risk avoidance travel, energy use and home repairs. In addition, the pronounced rise in social insurance and healthcare spending points to heightened attention to risk management and health needs in the aftermath of the earthquakes, highlighting an important dimension of household economic resilience.

Furthermore, the results show a sizeable and statistically significant increase in receipts and refunds, a category that in the HES primarily records insurance reimbursements and related inflows as negative expenditure items. Given New Zealand's near universal residential earthquake insurance coverage, this pattern is most plausibly interpreted as reflecting the large volume of insurance settlements and associated claim payments following the earthquakes, rather than deliberate shifts in household consumption behaviour.

In addition, the heterogeneity analysis within the treated group reveals significant differences between relocated households and those who remained in place in terms of housing tenure and housing-related costs. In descriptive statistics, relocated households also display less favourable income distributions and greater income volatility, although average income levels are similar once observable characteristics are controlled for. These findings underscore the close relationship between post disaster migration and household economic vulnerability and resilience (Fussell, 2015).

6.2 Limitations and directions for future research

This study has several limitations related to sample size and the measurement of income and expenditure in the HES. In particular, the use of short diary windows for detailed expenditures and self-reported aggregates may introduce annualisation and measurement error, and may increase sensitivity to atypical weeks or transient shocks.

Detailed expenditure in the HES is collected using an expenditure diary for selected households, supplemented by two expenditure questionnaire modules (Stats NZ, 2023a). Annualised expenditure measures are constructed from the diary records and reported payment frequencies. A key limitation is that a single week may not represent longer-run consumption patterns and can be affected by atypical events (including behavioural responses to diary-keeping) or seasonal spending. These features can introduce non-trivial measurement error in annualised category-level expenditure.

These measurement features may help explain why effects appear in some disaggregated expenditure categories while total expenditure shows no clear average effect. Category level measures are inherently noisier and may respond differently across households, and shifts in spending composition can offset at the aggregate level. Together, these factors can generate statistically significant movements in selected categories even when overall expenditure changes are small.

In addition, the data generating process differs across outcomes. Total income, regular income and total expenditure are based on direct self-reports by survey respondents rather than being derived from diary records or linked administrative sources such as Inland Revenue or bank records (Stats NZ, 2023a). Although respondents are encouraged to consult supporting documents (e.g., bank statements or tax returns), the final figures still rely on self-reported information. This raises the possibility of measurement error arising from recall difficulties, misclassification of income sources, and social desirability concerns. Such errors may increase noise and reduce statistical power, and any resulting bias need not be purely attenuating: depending on the nature of misreporting and its correlation with exposure status, estimates could be biased in either direction.

Because of these data constraints, the analysis is not able to examine in greater depth the heterogeneous effects of the earthquakes across groups defined by income source, ethnic background, levels of social capital (as a proxy for resilience) or household structure. In addition, the precision of the estimated effects, particularly when expressed in absolute monetary terms, may be limited.

Future research could build on this study in several directions. First, by leveraging larger-scale and higher-quality administrative household data, such as the Experimental Administrative Population Census in the IDI, it would be possible to compare results from household-level and individual-level analyses and to trace recovery dynamics over longer horizons. Though these administrative data do not typically include information about expenditures. Second, future work could investigate how the interaction between income distribution, housing conditions and social capital shapes post-disaster recovery trajectories, thereby providing a richer picture of distributional and spatial inequality in disaster impacts. Third, a systematic comparison of different household structures and intra-household labour divisions could yield valuable insights into the heterogeneous effects of disasters on household income and expenditure, as well as into the policy response mechanisms that could support or hinder recovery.

Through such extensions, researchers can develop a more comprehensive understanding of household resilience mechanisms and identify more effective policy options to strengthen socioeconomic resilience in the face of future shocks.

Several limitations qualify these conclusions. First, the HES is a repeated cross-section rather than a longitudinal household panel. The analysis therefore identifies changes in average outcomes across survey waves but cannot directly trace the same households before and after the earthquakes. Although matching is conducted separately within each wave and the pseudo-outcome tests show no systematic differential compositional changes, unobserved changes in sample composition cannot be completely excluded. Selective migration is a particularly relevant concern because households that left Canterbury differ from those that remained in age and housing tenure.

Second, the DiD interpretation relies on the assumption that exposed and matched comparison households would have followed parallel trends in the absence of the earthquakes. The event-study estimates and joint Wald tests provide supportive evidence for this assumption for total and regular household income, but statistical non-rejection does not prove that counterfactual trends were identical. For total expenditure, the parallel-trends assessment is substantially weaker because only one comparable pre-earthquake full-expenditure wave is available.

Third, income and expenditure in the HES are self-reported and are subject to recall, classification, and annualisation error. Diary-recorded expenditures are collected over a short observation window and may be affected by atypical purchases, seasonal variation, or behavioural responses to diary keeping. Retrospective expenditure modules may be subject to longer recall periods. These measurement features can reduce precision and may partly explain why significant movements appear in individual categories even when total expenditure shows no clear average effect.

The category-level transformation also imposes an interpretive limitation. The use of $\log(1+|y|)$ reduces the influence of extreme observations and facilitates proportional interpretation, but it removes the original sign of expenditure entries. This is especially relevant for receipts and refunds, where negative expenditure values can represent reimbursements or other inflows. The estimates therefore describe changes in the magnitude of these entries, not changes in their signed net contribution to household resources.

Fourth, pre-earthquake address histories cannot be recovered for a non-trivial share of HES reference persons. The similarity between missing-address patterns in the HES linkage and the Census-based comparison suggests that this problem largely reflects structural limitations in the administrative address data. Nevertheless, missingness is not necessarily random, particularly among young adults, highly mobile individuals, and people with periods overseas, and some selection risk remains.

Fifth, meshblock-level MMI captures local ground-shaking intensity but does not directly measure dwelling-level damage, repair costs, insurance coverage, or access to compensation. The low- and high-intensity categories necessarily simplify a continuous and spatially heterogeneous hazard. The absence of a significant linear continuous-MMI interaction further indicates that earthquake effects may depend on thresholds, local damage, housing characteristics, or institutional responses rather than on a uniform marginal increase in shaking intensity.

Finally, several heterogeneity analyses are constrained by sample size. This applies particularly to relocation households, income-specific expenditure models, and small address-classification groups. The migration estimates are also endogenous by construction and should not be interpreted as causal effects of moving. The ATT-IPW results, while directionally informative, are less precise than the matched-sample estimates and therefore do not provide identical statistical confirmation of the baseline effects.

Future research could address these limitations by combining longitudinal administrative income and employment records with household-linkage methods that follow individuals and family units over time. This would make it possible to distinguish changes in wages, labour supply, transfers, business income, and household composition, and to separate individual recovery from compositional changes in repeated cross-sections (Abdeljawad & Noy, 2025a). Linking more detailed property-damage, insurance-claim, tenure, mortgage, and residential-mobility information would help identify the mechanisms connecting hazard exposure to compensation, debt, repair, and relocation.

Further work could also examine heterogeneity by ethnicity, household structure, presence and age of children, housing tenure, employment sector, and social capital. These dimensions are likely to influence access to insurance, credit, informal support, and reconstruction opportunities. More frequent expenditure data or linked financial-transaction records would be especially valuable for distinguishing short-run emergency spending from longer-term changes in consumption and saving.

Overall, the Canterbury earthquakes produced neither a uniform economic loss nor a uniform recovery at the household level. Household incomes increased relative to the matched comparison group, but total expenditure did not change clearly on average, and the composition of spending shifted substantially. The scale and form of these adjustments differed by income, exposure intensity, and migration status. These findings demonstrate that disaster recovery cannot be evaluated adequately using aggregate income or output alone. A complete assessment must also account for insurance and reimbursement flows, housing and relocation costs, health and routine consumption needs, debt commitments, and the unequal resources households can mobilise during reconstruction.

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Appendices

Appendix A: Sample classification and missing address rates

Table A.1. Distribution of households across the four sample groups, by survey year⁴

Survey Year	Group 1	Group 2	Group 3	Group 4
2006/07	399	18	18	1890
2007/08	447	15	18	2349
2008/09	450	12	12	2304
2009/10	426	S	15	2088
2010/11	435	S	18	2454
2011/12	465	21	24	2385
2012/13	387	27	21	2040
2013/14	408	30	24	2253
2014/15	648	54	45	3744
2015/16	390	30	48	2367
2016/17	414	42	42	2526
2017/18	567	66	63	3774

⁴In all tables in this paper, the letter "S" indicates that the sample size for that cell in the given year is fewer than 6 and has been suppressed in accordance with Stats NZ confidentiality rules. All other numeric values have been subject to RR3 random rounding as required.

Table A.2. Unmatched pre-earthquake address records by HES survey year

Survey Year	Valid HES Households	Unmatched Addresses	Unmatched rate (%)
2006/07	2799	477	17.00%
2007/08	3393	561	16.50%
2008/09	3285	501	15.30%
2009/10	3033	492	16.20%
2010/11	3435	516	15.00%
2011/12	3450	555	16.10%
2012/13	2934	453	15.40%
2013/14	3363	645	19.20%
2014/15	5505	1014	18.40%
2015/16	3465	627	18.10%
2016/17	3675	645	17.60%
2017/18	5451	969	17.80%

Table A.3. Unmatched address rates from linkage to 2013 Census records

Survey Year	Matched	Unmatched	Unmatched Rate (%)
2006/07	2226	669	23.10%
2007/08	2691	804	23.00%
2008/09	2706	672	19.90%
2009/10	2580	543	17.40%
2010/11	2943	591	16.70%
2011/12	3006	555	15.60%
2012/13	2664	339	11.30%
2013/14	2922	462	13.70%
2014/15	4827	732	13.20%
2015/16	3069	426	12.20%
2016/17	3138	564	15.20%
2017/18	4629	846	15.50%

Appendix B. [Matching quality and compositional balance checks](#)

Table B.1 PSM matching quality—Max SMD and Variance Ratio by Survey Year

Survey Year	Max SMD	Max VR
2006/07	0.05	1.10
2007/08	0.07	1.08
2008/09	0.02	1.09
2009/10	0.02	1.09
2010/11	0.03	1.06
2011/12	0.05	0.97
2012/13	0.03	1.13
2013/14	0.04	1.01
2014/15	0.03	0.94
2015/16	0.02	1.04
2016/17	0.04	1.07
2017/18	0.03	1.16

Table B.2 Four-cell means of key covariates by treatment and post status

variable	treat	post	n_obs	mean_value	sd_value
age	0	0	1695	50.54	17.42
age	0	1	1659	54.89	17.07
age	1	0	846	50.77	17.75
age	1	1	831	54.29	17.56
household size	0	0	1695	2.46	1.27
household size	0	1	1659	2.36	1.31
household size	1	0	846	2.45	1.26
household size	1	1	831	2.34	1.31
female	0	0	1695	0.56	0.50
female	0	1	1659	0.60	0.49
female	1	0	846	0.55	0.50
female	1	1	831	0.60	0.49
own/trust	0	0	1695	0.69	0.46
own/trust	0	1	1659	0.70	0.46
own/trust	1	0	846	0.72	0.45
own/trust	1	1	831	0.72	0.45
higher education	0	0	1695	0.28	0.45
higher education	0	1	1659	0.29	0.45
higher education	1	0	846	0.29	0.46
higher education	1	1	831	0.30	0.46

Note: Treat = 1 denotes Canterbury households; Post = 1 denotes post-earthquake survey waves.

Table B.3 Pseudo-outcome DiD tests for key covariates

<u>variable</u>	<u>n obs</u>	<u>coef</u> <u>treat</u> <u>post</u>	<u>se</u> <u>treat</u> <u>post</u>	<u>p</u> <u>treat</u> <u>post</u>
age	5028	-0.83	0.85	0.33
household size	5028	-0.01	0.05	0.89
female	5028	0.00	0.02	0.86
own/trust	5028	-0.01	0.02	0.73
higher education	5028	0.00	0.02	0.84

Table B.4 Pseudo-outcome DiD tests for household-composition categories

<u>variable</u>	<u>n obs</u>	<u>coef</u> <u>treat</u> <u>post</u>	<u>se</u> <u>treat</u> <u>post</u>	<u>p</u> <u>treat</u> <u>post</u>	<u>weighting</u>
one-family household	17214	-0.01	0.01	0.43	unweighted
two-family household	17214	0.01	0.01	0.28	unweighted
three-plus-family household	17214	-0.01	0.01	0.32	unweighted
other multiperson household	17214	-0.01	0.01	0.34	unweighted
one-person household	17214	0.01	0.01	0.51	unweighted
unidentifiable household	17214	0.01	0.01	0.10	unweighted
nonfamily or one-person hhld	17214	0.01	0.01	0.28	unweighted
one-family household	17214	0.01	0.01	0.54	weighted
two-family household	17214	0.00	0.02	0.94	weighted
three-plus-family household	17214	0.00	0.01	0.78	weighted
other multiperson household	17214	-0.01	0.01	0.53	weighted
one-person household	17214	-0.02	0.01	0.22	weighted
unidentifiable household	17214	0.02	0.01	0.12	weighted
nonfamily or one-person hhld	17214	-0.01	0.02	0.75	weighted

Appendix C. [Event Study Plots for Parallel Trend Assumption Test](#)

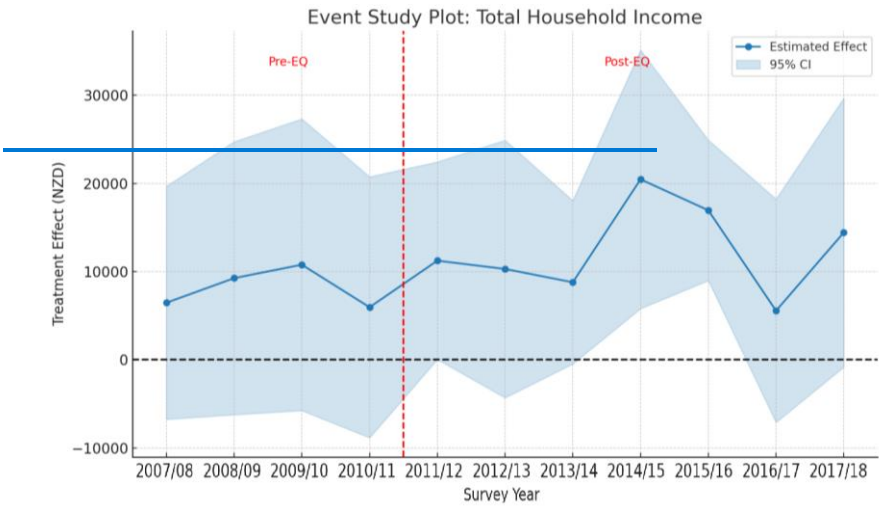
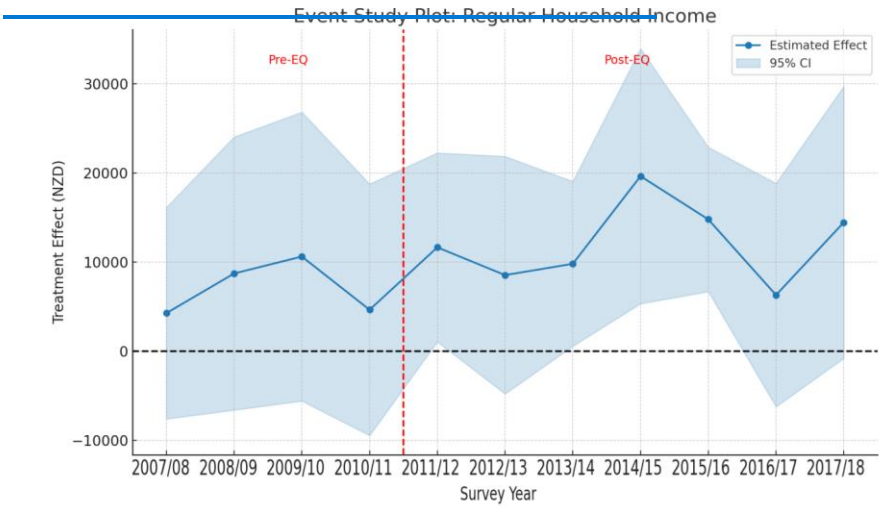


Figure C.1. Event-study estimates [for Total Household Income](#) and pre-trend tests



FigureTable C.21. Event-study estimates [for Regular Household Income](#)

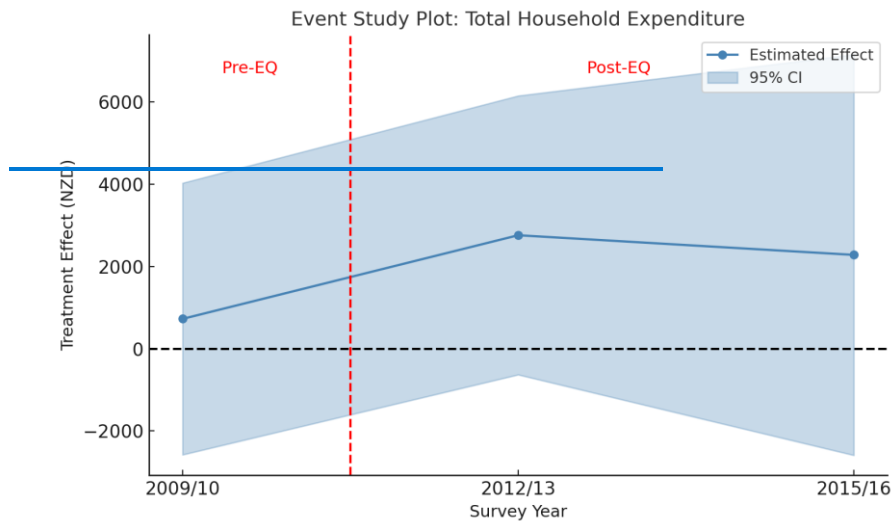


Figure C.3. Event study estimates for Total Household Expenditure

	<u>total household income</u>	<u>regular household income</u>	<u>total household expenditure</u>
<u>year = 0708 × treat (pre)</u>	<u>7712.23</u> <u>(7900.57)</u>	<u>5381.47</u> <u>(7447.81)</u>	
<u>year = 0809 × treat (pre)</u>	<u>10009.71</u> <u>(8882.54)</u>	<u>9576.58</u> <u>(8808.09)</u>	
<u>year = 0910 × treat (pre)</u>	<u>10277.22</u> <u>(9696.48)</u>	<u>9682.52</u> <u>(9336.30)</u>	<u>1057.73</u> <u>(1741.46)</u>
<u>year = 1011 × treat (pre)</u>	<u>9168.49</u> <u>(7961.18)</u>	<u>7480.27</u> <u>(7740.02)</u>	
<u>year = 1112 × treat (post)</u>	<u>13230.184</u> <u>(7190.26)</u>	<u>13528.07*</u> <u>(6712.10)</u>	
<u>year = 1213 × treat (post)</u>	<u>11666.19</u> <u>(9582.08)</u>	<u>10043.08</u> <u>(8942.25)</u>	<u>3128.01</u> <u>(1930.54)</u>
<u>year = 1314 × treat (post)</u>	<u>11939.18</u> <u>(6723.37)</u>	<u>11550.66</u> <u>(6106.45)</u>	
<u>year = 1415 × treat (post)</u>	<u>20425.94*</u> <u>(9421.72)</u>	<u>20450.81*</u> <u>(9290.82)</u>	
<u>year = 1516 × treat (post)</u>	<u>17783.92**</u> <u>(6212.52)</u>	<u>15547.38*</u> <u>(6080.73)</u>	<u>2830.61</u> <u>(2738.57)</u>
<u>year = 1617 × treat (post)</u>	<u>4558.82</u> <u>(6041.94)</u>	<u>4592.35</u> <u>(6105.49)</u>	
<u>year = 1718 × treat (post)</u>	<u>15085.98</u> <u>(10687.29)</u>	<u>14853.11</u> <u>(10230.82)</u>	
<u>age</u>	<u>3813.21***</u> <u>(304.91)</u>	<u>3464.62***</u> <u>(299.85)</u>	<u>1172.62***</u> <u>(99.32)</u>
<u>age²</u>	<u>-37.83***</u> <u>(3.06)</u>	<u>-34.60***</u> <u>(3.00)</u>	<u>-13.33***</u> <u>(0.96)</u>
<u>sex</u>	<u>-11895.73***</u> <u>(987.72)</u>	<u>-11688.95***</u> <u>(934.91)</u>	<u>-3386.70***</u> <u>(769.00)</u>
<u>household size</u>	<u>14079.33***</u> <u>(743.24)</u>	<u>13963.05***</u> <u>(720.67)</u>	<u>6807.11***</u> <u>(593.60)</u>
<u>Num.Obs.</u>	<u>17193</u>	<u>17193</u>	<u>5022</u>
<u>R2</u>	<u>0.14</u>	<u>0.15</u>	<u>0.36</u>
<u>R2 Adj.</u>	<u>0.14</u>	<u>0.14</u>	<u>0.35</u>
<u>R2 Within</u>	<u>0.1</u>	<u>0.11</u>	<u>0.15</u>
<u>R2 Within Adj.</u>	<u>0.1</u>	<u>0.11</u>	<u>0.15</u>
<u>Std.Errors</u>	<u>by: TA code</u>	<u>by: TA code</u>	<u>by: TA code</u>

* p < 0.05, ** p < 0.01, *** p < 0.001

Table C.2. Joint Wald tests of pre-earthquake coefficients

<u>outcome</u>	<u>test</u>	<u>statistic</u>	<u>p value</u>
<u>total household income</u>	<u>pre-trend joint Wald</u>	<u>0.39</u>	<u>0.81</u>

<u>outcome</u>	<u>test</u>	<u>statistic</u>	<u>p value</u>
<u>regular household</u>	<u>pre-trend</u>	<u>0.65</u>	<u>0.62</u>
<u>income</u>	<u>joint Wald</u>		
<u>total household</u>	<u>pre-trend</u>	<u>0.37</u>	<u>0.54</u>
<u>expenditure</u>	<u>joint Wald</u>		

Appendix D. Descriptive Statistics

Table D.1. Descriptive Statistics by Earthquake Intensity and Control Group Classification

Survey Year	Group	Counts	Household size		Ref_sex %Female	Housing		Total household income		Total household regular income		Total household expenditure		Housing cost		Mortgages and loans cost	
			Mean	SD		%Owned/Trust	Median	SD	Median	SD	Median	SD	Median	SD	Mean	SD	
2006/07	Treated	417	49.6	2.5	54.0%	73.4%	64357	56067.5	63046.4	55089.4	45611.9	34314.9	9308	43656.5	25118	54783.2	
	-Low	147	51.7	2.5	60.5%	85.7%	53790.5	37811.2	53289.7	37379.4	31652.1	27992.3	7529	21990.8	23040.7	47578.3	
	-High	270	48.5	2.4	51.1%	65.6%	54938.3	53458.5	54259.6	52027.7	38767.6	37179.4	10529.2	51191.7	26346.5	58473.4	
	Control	831	49.2	2.5	54.2%	67.5%	68761.8	54185.6	67350.9	53128.5	49739.4	41711.8	12480.3	36026.2	26093.9	54666.2	
2007/08	Treated	462	51.6	2.4	54.5%	71.4%	70301.9	84767.9	65753.1	56468.7	10538.8	10208.4	9102	34326.1	25366.2	48469.3	
	-Low	159	53.3	2.3	49.1%	73.6%	51768.6	46150.1	49807.9	41013.1	6830.7	8063.8	8571.8	19636.4	18654.5	37386.4	
	-High	297	50.5	2.5	57.6%	70.7%	55191	99493	53738.8	63034.4	10528.6	11035.6	9563.2	39756.4	29212.2	53319.7	
	Control	924	50.6	2.4	56.2%	66.9%	75385.2	75361.4	73243.6	69668.5	11512.2	12451.5	12457	34971	25877.7	63821.8	
2008/09	Treated	459	50.8	2.3	59.5%	69.9%	70666.2	69565.6	68583.4	67340.8	10049.2	9801.4	9600.7	41916.9	23598.4	52551.3	
	-Low	150	52.2	2.4	52.0%	78.0%	57180	84465.8	57180	81707.4	3910.7	8517.2	7236	31454	15289.3	35406.7	
	-High	306	50.2	2.3	63.7%	64.7%	56935	61228	53627.6	59283.1	8645.9	10249.9	11262.9	45948.1	27469.2	58914.4	
	Control	921	50.1	2.4	60.3%	65.8%	73543.9	72210.6	72179.9	70173.7	11657.7	12346.6	12884.3	52254.2	25221.3	64566.4	
2009/10	Treated	432	51.7	2.4	57.6%	70.8%	72656.9	72316	70499	70158.2	48909.3	33203.6	11855.8	49444.8	21351.5	44541.5	
	-Low	135	53.5	2.3	60.0%	75.6%	49969.2	101713.1	49969.2	100370	36842.3	27598.5	8817.5	24629.6	12933	30059.6	
	-High	294	50.9	2.5	58.2%	68.4%	59306.4	53813.5	58229.3	50705.9	44945.7	35100.1	13713.6	58292.2	25320.2	49470.6	
	Control	867	52.1	2.5	57.4%	67.8%	73793.7	66841.3	71960.4	64739	50816.5	36407.9	14165.9	53662.4	24036.5	59536.4	
2010/11	Treated	432	51.7	2.4	54.9%	70.8%	75699.9	68565.1	72469.3	63612.4	10409.3	9248.4	11531.3	41544.3	23744.8	48414.3	
	-Low	165	54.7	2.3	54.5%	80.0%	55872.4	49228.2	55872.4	40949.1	3076	7296.2	7538.3	23680.7	13885.6	31630	
	-High	267	49.8	2.5	55.1%	65.2%	63023.4	77767.8	60691.2	73826.6	11471.4	9810.5	15214.4	48373	29963.4	55617.7	
	Control	867	51.4	2.5	55.7%	66.4%	82139.7	78790.6	80312.9	74871.1	13325.5	14847.6	14235	48192.9	29323.3	66567.5	
2011/12	Treated	486	51.7	2.4	59.9%	67.9%	74452.6	61820.2	73046.9	61000.5	10664.5	10269.8	12822	82047.8	24249.6	64118	
	-Low	168	52.1	2.4	64.3%	73.2%	58914.3	76456.4	58914.3	76281.2	6470.3	7567.2	12304.7	20909.3	16072	37698	
	-High	312	51.6	2.4	56.7%	64.4%	62134.1	52676.9	60360.9	51316.7	8503.7	11312.4	13921.1	99026.9	28377.3	74466.6	
	Control	972	52.2	2.3	59.9%	64.2%	74060.4	64046.6	72457.7	62714.3	12736.6	11830.3	14020	42652.4	23521.3	53682.1	
2012/13	Treated	411	52.8	2.4	62.8%	71.5%	81298.6	83189.7	77624.8	77034.9	51844.2	33178.1	13893.2	45717.5	22435.7	49959.2	
	-Low	162	55.6	2.2	64.8%	81.5%	58639.3	48121	57527.3	44310.7	42478	26283.4	11112	20319.1	18423.9	34691.4	
	-High	246	50.8	2.4	61.0%	64.6%	65801.7	99454.8	63171.9	92149.9	47026.3	36671.7	16382.5	5550.9	25276.4	57949.6	
	Control	822	53.3	2.4	63.1%	67.5%	81347.4	83490	79490.7	81195.2	53823.7	41361.8	17002.7	53688.3	23630.5	56608.2	
2013/14	Treated	438	52.5	2.4	59.6%	71.2%	84491.6	92265.4	80831.4	66605.9	12044	11290.2	13452.3	71752.7	21013.9	44766.4	
	-Low	174	54.8	2.3	62.1%	77.6%	58407.3	58500.8	58059.7	56391.3	5560.7	10364	11638.7	28368.9	15100.8	31554.3	
	-High	258	51.3	2.4	59.3%	68.6%	65306.3	108628.5	65306.3	71203.3	10428.6	11860.4	17822.1	89559.1	25367.7	51795.6	
	Control	873	53	2.4	58.4%	68.4%	85110.4	83869.4	80480.6	72556	13849.7	16130.5	16263.2	48815.6	30211.5	77836	
2014/15	Treated	705	53.5	2.4	57.4%	68.5%	90790.8	79499	87540.6	73970.3	12599.3	13184.5	17623.6	60999.3	29568.5	72044.8	
	-Low	276	56	2.4	54.3%	79.3%	68774.3	68803.1	66349.4	64562.2	6302	14116.1	15705.1	25218.5	27010.9	71597.8	
	-High	381	52.7	2.5	59.8%	65.4%	76181.3	82555.7	74581.4	78678.1	10349.9	12898.6	20087.6	73035.6	33831.7	75223.5	
	Control	1407	53.6	2.4	57.8%	65.0%	81138.9	79995.4	78896.1	76931.4	13216.5	13555.3	16470.9	41896.1	25433.2	65626.7	
2015/16	Treated	420	55.7	2.3	57.1%	73.6%	86660.2	73841.7	82928.3	66300.7	12563.5	11205	21828.6	52092.7	33720.7	83451.3	

Survey Year	Group	Counts	Age	Household size		Ref sex		Housing		Total household income		Total household regular income		Total household expenditure		Housing cost		Mortgages and loans cost	
				Mean	SD	%Female	%Owned/Trust	Median	SD	Median	SD	Median	SD	Median	SD	Median	SD	Mean	SD
2016/17	-Low	186	57.9	2.3	58.1%	75.8%	67450.1	63738.4	67033.8	62304.5	7038.2	9893.1	21104.8	29328.1	30785.1	63720.1			
	-High	225	53.9	2.3	57.3%	72.0%	72157	81134	70191.3	69153.8	9508	12160	23508.9	64997.8	37427.5	97968.2			
	Control	840	55.9	2.3	56.8%	71.1%	80748.5	76421.3	79128.7	71456.3	13931	16181.6	21997.8	53715.5	34915	149370.3			
	Treated	456	55.1	2.4	54.6%	71.7%	87109.8	84423.4	84200.8	81756	13054.3	12826.2	21904.5	92275.3	34046.1	81449.2			
	-Low	177	56	2.4	54.2%	83.1%	72783	91954.2	69050.9	88930.5	5974.3	13523.2	20341.9	48042.3	38837.3	94530.5			
	-High	273	54.8	2.3	53.8%	64.8%	67284	79973.1	65545.2	77544.3	10417.9	12408.2	24158.3	112139.7	13458.3	72472.3			
2017/18	Control	909	55.5	2.3	56.8%	68.3%	90476	95165.5	86835.6	81678.3	14253.5	13765.5	21505.7	61104.5	35654.3	102838.4			
	Treated	633	53.7	2.3	55.0%	68.2%	92544.4	104170.4	90020.4	101953.1	14460	11991.1	27108.6	96966.1	37102.3	78344.9			
	-Low	255	54.8	2.3	57.6%	74.1%	66596.6	62110.4	64480	61366.4	11469.4	11940	23070	92862.6	36894.6	72329			
	-High	369	53.1	2.4	52.8%	63.4%	76510.6	125409.8	74052.7	122655.3	13035	12090.4	29198.4	99901.4	37432	82871.4			
2017/18	Control	1263	54.2	2.3	57.0%	63.7%	86898.4	99394.7	84527.9	95787.6	14336	13506.8	23580.1	60452	33655.1	82833			

Notes: (i) This table reports descriptive statistics by survey wave and exposure/control classification. Monetary variables are in NZD. For most

monetary outcomes we report medians together with a dispersion measure (SD). (ii) Mortgages and loans cost is reported as a mean (with SD)

because the distribution is strongly right-skewed; therefore, statistics across columns, especially those mixing means and medians, are not mechanically additive. (iii) The Stats NZ total household expenditure variable is not defined consistently across HES waves: in 2006/07, 2009/10,

2012/13 and 2015/16 it aggregates spending across all expenditure categories, whereas in the remaining waves it covers housing-related expenditure only (e.g., rent, mortgage payments, local authority rates and building insurance). Consequently, in housing-only waves, total household expenditure may appear close to housing cost plus mortgage repayments by construction. Where recorded separately in the HES classification, housing cost excludes mortgage repayments. Accordingly, the DiD analysis uses total household expenditure only in 2006/07, 2009/10, 2012/13 and 2015/16; other waves are shown here for descriptive purposes only. (iv) A small number of Canterbury meshblocks have very low seismic intensity ($MMI < 4$). These observations are included in the treated category in the descriptive tables because they are resident in Canterbury at the time of the earthquakes, but they are excluded from the DiD intensity-group specification and therefore do not enter the Low- or High-intensity groups, nor the control group.

Table D.2. Descriptive Statistics by Migration

Survey Year	Group	Counts	Age		Household size		Ref_sex		Housing		Total household income			Total household regular income			Total household expenditure			Housing cost			Mortgages and loans cost		
			Mean	SD	Mean	SD	%Female	%Owned/Trust	Median	SD	Median	SD	Median	SD	Median	SD	Median	SD	Mean	SD	Mean	SD			
2006/07	Relocation	18	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S			
	Stay	399	50	2.5	54.9%	74.4%	62448.4	48236.2	61079.9	46985.8	44800	33704.6	9074.6	43268.5	23502.4	47973.3									
2007/08	Relocation	15	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				
	Stay	447	51.9	2.4	55.0%	72.5%	70238.9	85952.1	65526.9	56971.9	10470.3	10303.8	8985.9	34118.5	25846	49144.7									
2008/09	Relocation	12	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				
	Stay	450	51.3	2.3	59.3%	70.0%	71128.9	70289.1	69058.3	68036.7	10097.4	9900.7	9570.3	41752.1	23994.9	53086.1									
2009/10	Relocation	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				
	Stay	426	51.9	2.4	57.7%	71.1%	72608.4	72365.9	70502.2	70316.2	48732	33152.6	11816.1	46818.3	21580.3	44750.2									
2010/11	Relocation	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				
	Stay	435	51.7	2.4	54.5%	70.3%	75699.9	68565.1	72469.3	63612.4	10409.3	9248.4	11531.3	41544.3	23744.8	48414.3									
2011/12	Relocation	21	42.2	3.2	S	S	57969.9	38186.8	57849.6	38183.4	16664	11513.2	61302.8	211406.7	14186.9	34283.4									
	Stay	465	52.2	2.3	59.4%	69.0%	75197	62601.9	73733.2	61771.4	10393.6	10140.3	12539.5	68271.3	24704.1	65128.5									
2012/13	Relocation	27	53.3	2.1	55.5%	44.4%	58116.9	43829.7	51231.3	26814.6	13988.1	63087.4	7268.6	21237											
	Stay	387	52.8	2.4	62.8%	72.9%	82864.1	85001.1	78942.2	78635.9	51885.6	33592.9	13893.2	44258.7	23460	51175.4									
2013/14	Relocation	30	41.4	2.4	60.0%	40.0%	77288.6	56194.2	77102.9	56320.7	18155.4	12085.6	28678.6	37718.9	20134.8	38166									
	Stay	408	53.4	2.4	59.6%	72.8%	85038.8	94468.5	81114.7	67374.3	11579.6	11106.3	13064.2	73680.9	21080.7	45268.5									
2014/15	Relocation	54	45.9	2.3	55.6%	44.4%	82883.6	101393.9	80950.5	99735.8	12894.6	9346.4	22942.8	82296.6	17962.8	51141.9									
	Stay	648	54.1	2.5	57.9%	70.8%	91461.9	77417.9	88099.9	71431.8	12574.3	13465.1	17287.5	58639.1	30553.5	73491.2									
2015/16	Relocation	30	48.9	2.6	50.0%	60.0%	82299.1	71753.2	77287.4	68710.8	14659	11511.1	22624	46080.7	26168.3	49464.9									
	Stay	390	56.3	2.3	57.7%	74.6%	87019	74089.5	83392.3	66168.5	12391.1	11177.1	21792	52608.1	34341.9	85661.6									
2016/17	Relocation	42	47.9	3	57.1%	64.3%	99701.6	100424.1	93235.5	94387.3	19767.7	16687.8	24045	241829.9	47791.5	88175.1									
	Stay	414	55.8	2.3	53.6%	73.2%	85862.8	82709.2	83306	80472.6	12389.4	12204.6	21531.5	57814.8	32684.8	80739.8									
2017/18	Relocation	66	44.7	2.4	50.0%	50.0%	125513	229835.2	123099.4	228960.8	18447	14496.8	34412.4	163711.7	29196.4	59267.8									
	Stay	567	54.7	2.3	55.6%	60.3%	88758.2	77310	86221.6	74240.9	14002.1	11596.7	26292.6	85904.1	38010.3	80238									

Notes: (i) This table reports descriptive statistics by survey wave and ~~exposure=control~~post-earthquake migration classification. Monetary variables are in NZD. For most monetary outcomes

we report medians together with a dispersion measure (SD). (ii) Mortgages and loans cost is reported as a mean (with SD) because the distribution is strongly right-skewed; therefore, statistics

across columns, especially those mixing means and medians, are not mechanically additive. (iii) The Stats NZ total household expenditure variable is not defined consistently across HES waves:

in 2006/07, 2009/10, 2012/13 and 2015/16 it aggregates spending across all expenditure categories, whereas in the remaining waves it covers housing-related expenditure only (e.g., rent, mortgage

payments, local authority rates and building insurance). Consequently, in housing-only waves, total household expenditure may appear close to housing cost plus mortgage repayments by

construction. Where recorded separately in the HES classification, housing cost excludes mortgage repayments. Accordingly, the DiD analysis uses total household expenditure only in 2006/07,

2009/10, 2012/13 and 2015/16; other waves are shown here for descriptive purposes only. (iv) Some cells are suppressed (S) where required by Stats NZ confidentiality rules.

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Appendix E. DiD Results for Expenditure Categories

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term	estimate	std.error	expenditure category	no bs
MMI group: Low × post	0.70***	0.15	general insurance	5016
MMI group: Low × post	0.02	0.42	general insurance	5016
MMI group: High × post	0.49*	0.19	household maintenance	5016
MMI group: Low × post	0.64	0.55	household maintenance	5016
MMI group: High × post	-0.08	-0.0921	household operations	5016
MMI group: Low × post	0.18***	0.78***	household operations	5016
MMI group: Low × post	-0.009*	-0.019***	household operations	5016
MMI group: Low × post	-0.003	-0.004	household operations	5016
MMI group: Low × post	0.15	0.68	household operations	5016
MMI group: High × post	0.06	0.02	housing costs	5016
MMI group: Low × post	0.31*	0.16	housing costs	5016
MMI group: High × post	0.0424	0.04	medical and health	5016
MMI group: Low × post	0.30	0.35	medical and health	5016
MMI group: High × post	0.037	0.32	miscellaneous payments	5016
MMI group: Low × post	0.01	0.56	miscellaneous payments	5016

MMI group: Low	×	post	0.02	0.26
MMI group: High	×	post	0.00	0.06
MMI group: Low	×	post	0.10	0.13
MMI group: High	×	post	0.73***	0.12
MMI group: Low	×	post	0.30	0.25
MMI group: High	×	post	0.27*	0.10
MMI group: Low	×	post	0.03	0.21

R2-Within MMI group: High × post

-0.0210

mortgages and loans	5016
other property	5016
other property	5016
receipts and refunds	5016
receipts and refunds	5016
telecommunications	5016
telecommunications	5016

R2-Within Adj. MMI group: High × post

0.0240*

0.15transportation

Adj. MMI group: Low × post

239360.18

24699.9transportation

Adj. MMI group: High × post

243860.45

25149.8travel

RMSEMMI group: Low × post

2.590.83

2.8travel

by:TA-code by:TA-code by:TA-code by:TA-code by:TA-code by:TA-code by:TA-code by:TA-code

* p < 0.05, ** p < 0.01, *** p < 0.001

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Appendix F. Median Household Income and Annual Growth of New Zealand regions in 2006 and 2013 (in NZD)

<u>Region</u> <u>region</u>	<u>Median</u> <u>median</u> Household Income (2006)	<u>Median</u> <u>median</u> Household Income (2013)	<u>Annual</u> <u>annual</u> Growth Rate (%)
Auckland	63,400	76,500	2.72%
Canterbury	47,900	65,000	4.46%
Wellington	59,700	74,300	3.17%
Waikato	49,400	59,600	2.72%
Bay of Plenty	45,400	54,600	2.67%
Hawke's Bay	44,200	53,200	2.68%
Manawatu-Wanganui	41,200	50,000	2.80%
Northland	40,200	46,900	2.23%
Southland	44,200	57,400	3.80%
Otago	44,400	56,400	3.48%
West Coast	37,800	55,000	5.50%
Marlborough	45,500	55,200	2.80%
Nelson	43,900	54,300	3.08%
Tasman	43,000	53,500	3.17%
Gisborne	41,000	50,500	3.02%
Taranaki	44,700	58,400	3.89%

Appendix G. Heterogeneous expenditure responses by income group

Table G.1. Expenditure classification of responses among households with household income higher than above the median income

	Contribution to housing costs	Telecommunications	General insurance	Transportation & miscellaneous payments	Telecommunications	Fees & fees and subs	Household maintenance	Receipts & refunds
MMI group: Low × post	0.3928* (0.6812)	0.2957 (0.4242)	0.3814 (0.424)	0.2335 (0.4586)	0.339 (0.214)	1.4731* (0.4645)	0.5882 (0.72)	0.56 (0.43)
MMI group: High × post	0.5114* (0.1505)	1.04*** (0.0719)	0.1489*** (0.16)	0.2367 (0.4133)	0.7730 (0.08)	0.3360 (0.28)	0.4698** (0.365)	0.8 (0.1)
ref="Rented (reference category: Owned/trust=Trust)	1.3027** (0.27)	-0.46*** (0.09)	0.77*** (0.1)	0.0815 (0.232)	0.450 (0.217)	-30.44*** (0.36)	-0.58*** (0.1)	-3.12*** (0.1)
sex	0.96801 (0.1206)	0.00207 (0.0510)	0.08810 (0.071)	0.04807 (0.13)	0.840 (0.1206)	0.07900 (0.409)	0.04318 (0.2428)	-0.1 (0.1)
log income	0.34*** (0.009)	0.33*** (0.0612)	1.5073*** (0.12)	1.0080 (0.2018)	0.45** (0.20)	1.7569** (0.20)	1.6867*** (0.20)	0.4 (0.2)
age	0.07*** (0.01)	-0.01 (0.02)	0.11** (0.03)	0.08** (0.03)	0.04* (0.02)	0.02 (0.04)	0.12 (0.0)	0.12 (0.0)
ageage ²	0.00*** (0.00)	0.00 (0.00)	0.00* (0.00)	0.00** (0.00)	0.00 (0.00)	0.001** (0.00)	0.017** (0.00)	0.01 (0.00)

	0.00690	(0.002)00	0.00500	(0.006)00	0.00300	(0.005)00	(0.006)00	(0.006)
	0					0		-0.06
household size	0.1319*	-0.04	0.15*	0.18**	0.1714	0.17*	0.06	
	19*			**	**	**		
	7							
	2	(0.06)	7	(0.030)	4	(0.06)	(0.0307)	
Num. Obs.	250	2508	2508	2508	250	2508	2508	2508
R2	0.12174	0.18046	0.07077	0.07192	0.1061	0.17163	0.1312	0.15
R2 Adj.	0.1154	0.16023	0.05054	0.05172	0.0803	0.14142	0.1110	0.1
R2 Within	0.05121	0.12015	0.04058	0.05045	0.0604	0.12118	0.110	0.1
R2 Within Adj.	0.05118	0.12011	0.04054	0.04042	0.0503	0.1115	0.110	0.1
AIC	14488.2	8677.3	10582.1	14001.5	14156.5	14714.1	12724	
BIC	14861.1	9050.2	10955.1	14374.4	14529.4	15087	13099	
RMSE	4.23	1.33	1.94	3.84	3.96	4.43	2.5	
Std. Errors	by: TA cod	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code

*p < 0.05, ** p < 0.01, *** p < 0.001

Table G.2. Expenditure ~~classification of responses among~~ households ~~with household~~
~~income lower than~~below the median ~~income~~

	Diary Receipts & receipts and refunds	medical and health	diary	travel
MMI group: Low × post	0.0408 (0.4828)	0.0518 (0.2941)	0.07 (0.19)	1.19* (0.59)
MMI group: High × post	0.14* (0.0611)	0.3035* (0.1216)	0.17* (0.07)	0.07 (0.32)
ref = "Rented (reference category: Owned/trust"Trust)	0.66*** (0.1012)	0.2571*** (0.1319)	-0.56*** (0.09)	-1.29*** (0.16)
sex	-0.03 (0.08)	-0.1203 (0.12)	-0.058 (0.06)	-0.047 (0.13)
log_income	0.24*** (0.02)	0.06*** (0.07)	0.21*** (0.05)	0.23*** (0.0207)
age	0.02 (0.01**)	0.03 (0.01*02)	0.05*** (0.02)	0.08** (0.03)
age ²	-0.00* (0.00)	-0.00 (0.00)	-0.00*** (0.00)	-0.00** (0.00)
household size	0.47*** (0.04)	0.12 (0.0410)	0.48*** (0.03)	0.13 (0.12)
Num. Obs.	2508	2508	2508	2508
R2	0.19	0.03	0.08	0.11
R2 Adj.	0.17	0.00	0.05	0.08
R2 Within	0.1601	0.0002	0.17	0.03
Adj.	0.00	0.02	0.17	0.03
AIC		8760.2		10914.7
BIC		9162.2		11316.8
RMSE		1.35		2.07
Std. Errors	by: TA code	by: TA code	by: TA code	by: TA code

* p < 0.05, ** p < 0.01, *** p < 0.001

Appendix H. Alternative intensity and functional-form checks

Table H.1. Continuous-MMI specification

	<u>total</u> <u>income</u>	<u>householdregular</u> <u>income</u>	<u>householdtotal</u> <u>expenditure</u>	<u>household</u> <u>expenditure</u>
<u>age</u>	3957.43*** (270.43)	3491.72*** (241.24)	1278.85*** (136.42)	
<u>age2</u>	-39.31*** (2.58)	-35.00*** (2.19)	-14.05*** (1.48)	
<u>sex</u>	-11585.84*** (1426.55)	-11206.81*** (1273.90)	-3406.79*** (465.44)	
<u>Household size</u>	15016.62*** (492.31)	14795.02*** (471.05)	8219.67*** (601.35)	
<u>mmi_intensity × post</u>	-1114.46 (1917.09)	-1036.31 (1790.38)	-1001.20 (630.66)	
<u>Num. Obs.</u>	5697	5697	1662	
<u>R²</u>	0.15	0.17	0.43	
<u>Adjusted R²</u>	0.14	0.16	0.42	
<u>Within R²</u>	0.12	0.13	0.23	
<u>Adjusted Within R²</u>	0.11	0.13	0.23	
<u>Std. Errors</u>	by: TA code	by: TA code	by: TA code	

* p < 0.05, ** p < 0.01, *** p < 0.001

Table H.2. Bridge specifications with alternative age controls

	<u>total household</u>		<u>regular household</u>		<u>total household</u>		<u>regular household</u>		<u>total household</u>		<u>regular household</u>		<u>total household</u>	
	<u>income, age</u>	<u>expenditure, age</u>	<u>income, age</u>	<u>expenditure, age</u>	<u>income, age</u>	<u>expenditure, age</u>	<u>income, age</u>	<u>expenditure, age</u>	<u>income, age-bin</u>	<u>expenditure, age-bin</u>	<u>income, age-bin</u>	<u>expenditure, age-bin</u>	<u>income, age-bin</u>	<u>expenditure, age-bin</u>
mmi group =	5957.074*	3409.32	6910.070*	7043.473*	7924.418**	3413.71	7713.664**	3517.84	6804.016*	7713.664**	7199.692***	3517.84	6804.016*	7713.664**
Low × post	(2975.07)	(2325.26)	(2827.29)	(2889.43)	(2673.83)	(2507.03)	(2569.90)	(2456.78)	(2800.89)	(2569.90)	(2456.78)	(2456.78)	(2800.89)	(2569.90)
mmi group =	7152.296*	1818.91	7330.460*	7251.790*	7411.856*	2010.89	7525.615*	2019.98	7367.213*	7525.615*	7199.692***	2019.98	7367.213*	7525.615*
High × post	(3278.08)	(1399.49)	(3026.27)	(3559.44)	(3286.86)	(1469.80)	(3383.48)	(1450.39)	(3669.48)	(3383.48)	(3383.48)	(1450.39)	(3669.48)	(3383.48)
age	-181.587***	-238.167***	-188.441***	3810.439***	3462.944***	1170.946***	1170.946***	1170.946***	14782.474***	14656.381***	7199.692***	1170.946***	14782.474***	14656.381***
	(23.84)	(21.35)	(24.10)	(301.28)	(295.27)	(100.93)	(100.93)	(100.93)	(692.90)	(670.47)	(595.74)	(100.93)	(692.90)	(670.47)
household size	14965.277***	7139.099***	14766.590***	14074.521***	13960.682***	6805.154***	6805.154***	6805.154***	14782.474***	14656.381***	7199.692***	6805.154***	14782.474***	14656.381***
	(734.27)	(589.71)	(705.13)	(740.65)	(718.84)	(594.64)	(594.64)	(594.64)	(692.90)	(670.47)	(595.74)	(594.64)	(692.90)	(670.47)
age ²				-37.827***	-34.604***	-13.324***	-13.324***	-13.324***						
				(3.04)	(2.97)	(0.97)	(0.97)	(0.97)						
sex				-11894.360***	-11689.336***	-3388.781***	-3388.781***	-3388.781***	-12357.616***	-12116.284***	-3550.438***	-3388.781***	-12357.616***	-12116.284***
				(991.53)	(944.59)	(768.82)	(768.82)	(768.82)	(1060.61)	(1016.00)	(809.24)	(1060.61)	(1060.61)	(1016.00)
age bin = <25									-10892.041***	-10806.575***	-4478.207**	-10892.041***	-10806.575***	-4478.207**
age bin = 45-64									(3023.78)	(3193.55)	(1357.84)	(3023.78)	(3193.55)	(1357.84)
									18122.426***	15565.734***	2468.111*	18122.426***	15565.734***	2468.111*
age bin = 65+									(902.79)	(931.60)	(1086.21)	(902.79)	(931.60)	(1086.21)
									-13045.425***	-12643.043***	-10875.653***	-13045.425***	-12643.043***	-10875.653***
									(1749.74)	(1710.35)	(1046.37)	(1749.74)	(1710.35)	(1046.37)
Num.Obs.	17193	5022	17193	17193	17193	5022	17193	5022	17193	17193	5022	17193	17193	5022
R2	0.11	0.34	0.12	0.14	0.15	0.36	0.15	0.36	0.14	0.15	0.36	0.15	0.14	0.36
R2 Adj.	0.11	0.33	0.12	0.14	0.14	0.35	0.14	0.35	0.14	0.14	0.35	0.14	0.14	0.35
R2 Within	0.07	0.13	0.08	0.10	0.11	0.15	0.11	0.15	0.10	0.11	0.15	0.11	0.10	0.15
R2 Within Adj.	0.07	0.13	0.08	0.10	0.11	0.15	0.11	0.15	0.10	0.11	0.15	0.11	0.10	0.15
Std.Errors	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code

* p < 0.05, ** p < 0.01, *** p < 0.001

Appendix I. Alternative weighting estimator and bridge specifications

Table I.1. ATT-IPW bridge specifications for household regular income

	A. PSM with basic controls	B. PSM with main controls	C. PSM + richer controls	D. IPW full pool, unweighted	E. IPW full pool, ATT-IPW	F. IPW full pool, IPW + richer controls	G. IPW full pool, ATT-IPW + composition	H. IPW full pool, trimmed ATT-IPW + richer controls
mmi_group = Low × post	6847.60* (2767.78)	7924.42** (2673.83)	4543.965 (2519.99)	5103.907 (2763.36)	6846.41 (4464.09)	6821.11 (4701.83)	5372.5 (4427.00)	5516.69 (4335.10)
mmi_group = High × post	7398.89* (3065.04)	7411.86* (3286.86)	7895.02* (3432.49)	5755.759 (2898.55)	9957.33 (8324.29)	11747.76 (8831.25)	12670.65 (8243.96)	10918.58 (7457.45)
age	-188.107*** (24.11)	3462.94*** (295.27)	2825.33*** (271.86)	-165.067*** (47.32)	-186.866*** (31.62)	3194.79*** (281.34)	3139.52*** (302.21)	3132.37*** (290.16)
household size	14766.51*** (704.69)	13960.68*** (718.84)	13960.68*** (718.84)	12803.28*** (833.67)	15470.20*** (564.79)	13692.62*** (619.66)	4062.07*** (924.68)	13675.93*** (594.61)
age ²		-34.60*** (2.97)	-30.756*** (2.90)			-34.54*** (3.10)	-33.64*** (3.11)	-33.97*** (3.16)
sex		-11691.51*** (944.59)	-11689.34*** (959.81)			-11041.91*** (677.67)	-5772.921*** (854.51)	-11047.16*** (623.82)
Rented (reference category: Owned/Trust)			-37117.03*** (3431.99)			-34547.85*** (3184.62)	-27974.08*** (3001.50)	-34825.30*** (3040.81)
hh_comp:One-family household							-8885.78** (3077.83)	
hh_comp:One-person household							-47288.630*** (3066.75)	
hh_comp:Other multi-person household							-7764.16 (4921.72)	
hh_comp:Other or sparse composition							-12867.02 (10515.28)	
hh_comp:Three-or-more-family household							-48911.52*** (3376.42)	
hh_comp:Two-family household							-1194.05 (4178.82)	
Num.Obs.	17193	17193	17193	30384	30384	30384	30384	30384
R2	0.12	0.15	0.18	0.11	0.12	0.17	0.21	0.17
R2 Adj.	0.12	0.14	0.17	0.11	0.12	0.17	0.2	0.17
R2 Within	0.08	0.11	0.14	0.06	0.08	0.13	0.17	0.13
R2 Within Adj.	0.08	0.11	0.14	0.06	0.08	0.13	0.17	0.13
Std.Errors	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code

* p < 0.05, ** p < 0.01, *** p < 0.001

Table I.2. ATT-IPW bridge specifications for total household income

	A. PSM withB. PSM withC. PSM + richerD. IPW full poolE. IPW full poolG. IPW full poolH. IPW full pool			F. IPW full poolG. IPW full poolH. IPW full pool		
	basic controls	main controls	controls	unweighted	ATT-IPW	richer controls
mmi_group = Low × post	5899.80* (2938.53)	7043.47* (2889.43)	3498.53 (2693.56)	4418.52 (2921.07)	6734.3 (4465.03)	5234.9 (4428.02)
mmi_group = High × post	7210.27* (3312.97)	7251.79* (3559.44)	7747.01* (3710.14)	5806.342 (3128.71)	10353.18 (8900.27)	13211.16 (8834.39)
age	-181.299*** (23.85)	3810.44*** (301.28)	3139.60*** (286.54)	-152.085*** (47.35)	-176.759*** (32.18)	3458.83*** (331.21)
household size	14965.20*** (733.90)	14074.52*** (740.65)	13352.17*** (720.08)	12995.95*** (870.46)	15813.16*** (616.96)	3981.21*** (11029.99)
age ²		-37.83*** (3.03)	-33.78*** (3.02)		-37.68*** (3.35)	-37.22*** (3.31)
sex		-11894.36*** (991.53)	-11894.36*** (991.53)		-5941.29*** (950.53)	-11359.47*** (778.92)
Rented (reference category: Owned/Trust)			-39042.72*** (3537.03)		-36428.69*** (3250.95)	-36787.37*** (3136.11)
hh_comp:One-family household					-11361.77*** (821.14)	
hh_comp:One-person household					-37.68*** (3.35)	
hh_comp:Other multi-person household					-48169.41*** (3868.33)	
hh_comp:Other or sparse composition					-6972.53 (5209.46)	
hh_comp:Three-or-more-family household					-13522.24 (9749.48)	
hh_comp:Two-family household					-48924.73*** (4050.59)	
Num.Obs.	17193	17193	17193	30384	30384	30384
R2	0.11	0.14	0.17	0.1	0.11	0.16
R2 Adj.	0.11	0.14	0.16	0.1	0.11	0.16
R2 Within	0.07	0.1	0.13	0.06	0.07	0.12
R2 Within Adj.	0.07	0.1	0.13	0.06	0.07	0.12
Std.Errors	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code

* p < 0.05, ** p < 0.01, *** p < 0.001

Table I.3. ATT-IPW bridge specifications for total household expenditure

	A. PSM with B. PSM with		C. PSM	+D. IPW	fullF. IPW	fullF. IPW	fullF. IPW	G. IPW full pool	H. IPW full pool
	basic controls		richer controls	pool	pool	pool	pool	ATT-IPW	trimmed ATT-IPW
	main controls	main controls	richer controls	unweighted	unweighted	unweighted	unweighted	+ composition	+ richer controls
mmi_group = Low × post	3287.32 (2326.64)	3413.71 (2507.03)	2613.99 (2471.88)	2703.8 (2234.89)	1159.57 (1821.58)	693.99 (1900.64)	526 (1845.68)		1366.04 (2040.79)
mmi_group = High × post	1806.18 (1414.29)	2010.89 (1469.80)	2111.11 (1462.83)	1194.03 (1330.82)	-644.640 (1203.53)	265.85 (1226.89)	602.56 (1218.57)		682.18 (1242.00)
age	-238.211*** (21.37)	1170.95*** (100.93)	1055.66*** (107.00)	-225.629*** (28.85)	-229.062*** (25.47)	1184.77*** (144.16)	1172.51*** (175.01)		1164.73*** (133.09)
household size	7137.82*** (590.43)	6805.15*** (594.64)	6686.32*** (593.34)	6247.51*** (526.25)	7851.63*** (715.12)	7289.10*** (712.51)	4318.29*** (551.14)		7175.53*** (696.81)
age ²		-13.32*** (0.97)	-12.66*** (0.99)			-13.89*** (1.21)	-13.79*** (1.49)		-13.70*** (1.12)
sex		-3388.78*** (768.82)	-3366.05*** (779.15)			-3364.48*** (714.60)	-1255.97* (538.00)		-3438.09*** (682.75)
Rented (reference category: Owned/Trust)			-9521.24*** (1185.35)			-8881.61*** (1130.73)	-6387.90*** (1099.68)		-8857.47*** (1182.48)
hh_comp:One-family household							969.14 (2571.16)		
hh_comp:One-person household							-13436.20*** (2013.80)		
hh_comp:Other multi-person household							-2672.37 (1350.09)		
hh_comp:Three-or-more-family household							-17652.56*** (2755.51)		
hh_comp:Two-family household							1217.42 (1792.02)		
Num.Obs.	5022	5022	5022	5022	8406	8406	8406		8406
R ²	0.34	0.36	0.36	0.36	0.33	0.38	0.41		0.39
R ² Adj.	0.33	0.35	0.36	0.36	0.33	0.38	0.41		0.38
R ² Within	0.13	0.15	0.15	0.16	0.11	0.19	0.22		0.18
R ² Within Adj.	0.13	0.15	0.15	0.16	0.11	0.19	0.22		0.18
Std.Errors	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code	by: TA code

* p < 0.05, ** p < 0.01, *** p < 0.001

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Code and data availability

The data used in this study are not publicly available due to access restrictions and confidentiality requirements. The primary microdata are from Stats NZ’s Household Economic Survey (HES) and were accessed within the Stats NZ Integrated Data Infrastructure (IDI) under an approved project MAA2024-54 in accordance with the *Data and Statistics Act 2022* and Stats NZ microdata access protocols.

Researchers who meet the eligibility criteria may apply to access these data via Stats NZ’s Data Lab and the IDI. Access procedures and conditions are available from Stats NZ.

To support reproducibility, the empirical code (data cleaning scripts, variable construction, and estimation routines) and documentation sufficient to replicate the reported tables and figures will be made available in a GitHub upon acceptance. If an embargo is required, the repository will provide time-stamped releases and version tags, and the materials can be shared with reviewers through the Copernicus “access limited to reviewers” mechanism during peer review.

Supplement link

Not applicable at this stage.

Team list

Not applicable.

Author contributions

Quanfu Zhang: Conceptualization; Data curation; Formal analysis; Methodology; Software; Visualization; Writing – original draft.

Ilan Noy: Conceptualization; Methodology; Supervision; Writing – review & editing.

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Competing interests

The authors declare that they have no competing interests.

Disclaimer

Disclaimer for output produced from Stats NZ surveys

Access to the data used in this study was provided by Stats NZ under conditions designed to give effect to the security and confidentiality provisions of the *Data and Statistics Act 2022*. The results presented in this study are the work of the author, not Stats NZ or individual data suppliers.

Disclaimer for output produced from the IDI

These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit <https://www.stats.govt.nz/integrated-data/>

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