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11085
2024

April 2024

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CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
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CESifo *Working Paper No. 11085*

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Abstract

People are sometimes forced to move, and it has often been hypothesised that such relocation involves significant psychological costs. The challenge in identifying the mental health consequences of moving is that most moves are (partly) voluntary. We use a natural experiment, the mandated relocation of some households after an exogenous shock, to identify the causal impact of moving on people's mental health. The event we focus on is the 2011 Christchurch (New Zealand) earthquake, and the consequent decision of the central government to relocate about 8000 households from some of the affected area. We use a comprehensive administrative dataset that includes health records with information on hospital attendance, specialist services, and prescribed medications for (almost) every resident in the city. We find a statistically significant increase in the likelihood and frequency of receiving treatment for moderate mental health problems among individuals compelled to relocate, when compared to other residents of the earthquake-affected city who were allowed to remain in situ. This increase persisted to December 2013 for everyone but remained significant for the elderly across the whole examined period to the end of 2018. We found no such increase for more severe mental health incidents that required more acute interventions.

JEL-Codes: I100, Q540.

Keywords: mental health, managed retreat, disaster risk, relocation, difference-in-difference.

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This project was partially supported by QuakeCoRE, a New Zealand Tertiary Education Commission-funded Centre (publication #956), the Whakahura Endeavour Programme, and the Resilience National Science Challenge.

IDI disclaimer: The results in this paper are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) managed by Statistics New Zealand. Access to the anonymised data used in this study was provided by Statistics New Zealand in accordance with security and confidentiality provisions of the Statistics Act 1975. The findings are not Official Statistics. The results are based on tax data supplied by Inland Revenue to Statistics NZ under the Tax Administration Act 1994. This tax data must be used only for statistical purposes, and no individual information may be published or disclosed in any other form or provided to Inland Revenue for administrative or regulatory purposes. Any person who has had access to the unit record data has certified that they have been shown, have read, and have understood section 81 of the Tax Administration Act 1994, which relates to secrecy. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes and is not related to the data's ability to support Inland Revenue's core operational requirements. The opinions, findings, recommendations, and conclusions expressed in this paper are those of the author(s), and not Statistics NZ.

1. Introduction

People are sometimes forced to move, and it has often been hypothesised that such relocation involves significant economic, social, and psychological costs. Most obvious income potential that arises because of the loss of location-specific skills that the migrant/mover possessed, and the connections with occupations for which the migrant has trained for; though these are much more likely to manifest if the move is long-distance, and more if it also crosses linguistic, cultural, or international borders. Equally, migration also involves significant loss of cultural, linguistic, and social connections (i.e., social capital) that directly lead to a loss in wellbeing; again the longer the distance of the move is, the more likely it is to involve the loss of social capital. Simlarly, migration may exact psychological costs that originate from 'place attachment' or from other changes that are associated with the process of moving. It is these psychological costs—the ones that may manifest in mental health challenges—that are the focus of this paper.

The challenge in identifying the mental health consequences of moving is that most moves are voluntary, i.e., based on the individual's (or household's) decision and initiated by them. This self-selection therefore prevents any differences between observed outcomes in those people who move, and those who don't, to be causally associated with the move itself. Put differently, this selection makes it is impossible to identify any causal impact of such moves. Even after a sudden disaster that, for example, may destroy a person's house, the a choice whether to move or stay in situ is made (even if it is constrained differently than in moves that are not triggered by external shocks).

This, however, is not the case if the move is mandated, and is largely random (in the sense that this mandate to move is unlikely to be correlated with any pre-move characteristics of the movers). We use a natural experiment, the mandated relocation of some households after an exogenous shock, to identify the causal impact of moving on people's mental health. The event we focus on is the Christchurch (New Zealand) earthquake of 2011, and the consequent decision of the government to relocate about 8000 households from the affected area, because of a risk of liquefaction. This liquefaction, a geological process that makes the water table rise and soil 'liquify', made re-building too costly for the public insurer in the aftermath of the earthquake. Elsewhere, in some cases, the earthquake also led to an unexpected increase in landslide and cliff collapse risk, which made re-building houses in those areas too dangerous.

The earthquake sequence that culminated in the 2011 event, and generated this relocation programme, started in September 2010, with an earthquake in Darfield, east of the city of Christchurch. This earthquake caused extensive damage to some buildings and infrastructure, but few deaths. However, a shallower aftershock that occurred on the 22nd of February 2011 was centred much closer to the centre of the city, led to much more extensive damage. It, most tragically, killed 185 people. As some of the deaths occurred in buildings whose structural integrity was damaged in the earlier 2010 earthquake, this event led to a wholesale re-examination of risk in the city, including a two-year cordon of the business centre of the city, widespread demolitions of damaged large office buildings (where the majority of the deaths occurred), and a re-assessment of the viability of some residential areas.

Most of the city of Christchurch, with around 400,000 people, lies on a very flat area (the Canterbury Plains) close to the east coast of the South Island, with rivers running through it. The centre of the city consisted of mostly office and commercial buildings of several stories, and much of the rest of the city was (and still is) composed of suburban single-family homes. To the south-east of the city centre is a peninsula of volcanic origin and it contains some of the more expensive suburbs.

The earthquake caused a rise of the water-table that led to widespread liquefactions in several areas, especially along the Avon and Waimakariri Rivers. It also caused some rockfalls, cliff collapses, and slope instability in the volcanic peninsula. Overall, practically every building in the city incurred at least some damage from the earthquake sequence. In June 2011, the government decided to reclassify some of these liquefaction and cliff-collapse areas as Residential Red Zones (RRZ). In those areas, buildings were found to be uneconomic to repair or too risky to inhabit. Homeowners were told that these areas would no longer be permitted for residential use, and they were required to move away. The government offered to compensate the owners by offering to purchase their house and land at their pre-earthquake values.[1] This decision ultimately affected 8,060 houses and more than 16,000 people across Greater Christchurch (MacDonald et.al., 2016, Nguyen, 2020).[2] As such, this was an exceptionally large relocation program, even when compared to those implemented in much bigger countries (Hino et al., 2017).

A mandated relocation, such as the Christchurch RRZ may be associated with adverse psychological outcomes for those who are forced to relocate. If these relocations are exogenously determined (i.e, they are unanticipated and uncorrelated with any pre-event characteristics of the affected individuals) one can determine these impacts were causal. Involuntary relocation is recognized as a potentially stress-inducing and even traumatic experience. Such transitions have been shown to directly influence mental health outcomes within affected populations. Ellis (2010), for example, underscores the highly stressful nature of psychological transitions associated with relocation.

The case of the Christchurch RRZ is interesting not only because of its size and 'exogenous' origin, but also as relocated residents did not have to move far away and were fully compensated for the value of the property they were surrendering to the government. Because of that, these relocated individuals were not forced to change their employment and did not have to severe their links with their community, society, and cultural milieu. Still, relocation may have led to some voluntary changes in employment and some modest reductions in income for some groups (mostly young women – see Hoang and Noy, 2023). It is therefore a case where any adverse mental health consequences identified are more likely to be a result of the relocation itself than indirectly due to the impacts it generated (such as by reducing income or wealth).

We use the Integrated Data Infrastructure (IDI), an administrative database collected and maintained by Statistics NZ (the country's statistical agency). The IDI has several advantages for us. These data are comprehensive, and thus provide large, diverse, and representative samples of the population (very few people are not included), which allows us to reach robust conclusions about the populations being examined. They also allow for ongoing tracking of issues over time, in a panel set up over and an extended period.

The IDI includes administrative health data with information on hospital attendance, community care specialist services, and prescribed medications, and thus hold significant potential for health research. In particular, we believe their potential for mental health research has not yet been fully realized. Here, we investigate the impact of the forced RRZ relocation on mental health. As we have individual records of practically all the residents of Christchurch, we can further identify these impacts across various sub-samples including distinguishing by gender, age, income, and ethnicity. Finally, we can identify the longer-run effects of relocation on the RRZ residents, as long as they stayed in NZ (and were thus observable in the NZ government's records).

Our investigation is tangentially related to several other literatures, though as far as we are aware none has asked the question we ask here, using a causal-identification strategy like the one we use here: What are the mental health consequences of being forced to relocate?

The epidemiological literature has examined the mental health consequences of disasters before, mostly asking whether Post Traumatic Stress Disorder (PTSD) and Major Depressive Disorder (MDD) are generated by these disasters. It generally finds that PTSD and MDD often occur jointly in those affected by catastrophic events – see the reviews by Goldmann and Galea (2014), Rataj et al. (2016) and Beaglehole et al. (2018).[3] Most of this research relies on before-after comparisons of prevalence rates in affected communities, without typically an ability to control for other time variant effects and without access to individual records. Even when individual records are available, they are usually aggregated spatially and prevalence rates are then compared across affected and un-affected areas. Several studies have found an inverse relationship between age and adverse mental health outcomes in adults following natural disasters. Norris et al. (2002), for example, reported that middle-aged adults exhibit the highest risk for distress and subsequent mental health issues.

Another strand focused specifically on forced relocations due to disasters, but these were not because of an exogenous government mandate but these relocations happened because of the destruction experienced or the loss of income sources caused people to move (e.g., Fussell and Lowe, 2014). As such, it was impossible to separate the impact of relocation from the impact of the disaster itself. A different literature looks at relocations in other contexts, most of it voluntary. Again, selection issues prevent any clear causal assignment of the relocation to measurable mental health outcomes. An exception is Osypuk et al. (2012), who rely on a randomised control trial, but this trial targeted specifically vulnerable populations living in poor neighbourhoods and moved them, after a random assignment, to wealthier ones. Its findings are therefore likely only generalizable to this specific context.

A group of papers analysed the post-earthquake prevalence of prescribing of psychological medications in Christchurch specifically. These papers largely looked at the difference in prevalence rate of various treatments in the earthquake-affected areas and compared these to unaffected areas elsewhere. These include: Beaglehole (2019 & 2020) which used psychiatric prescription medication data for the elderly and youth, respectively; Greaves et al., 2015) which used a longitudinal survey; and Hogg et al. (2014, 2016a) which used Ministry of Health data. The closest investigation to ours is Hogg et al. (2016b), which examined the impact of relocation on individuals affected by the Christchurch earthquake, when compared to individuals who did not relocate. As noted earlier, this type of investigation suffers from selection bias, since the relocation was often voluntary, even if it followed from the earthquake.

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The next section details the data we use, section 3 describes their statistical characteristics and section 4 outlines our econometric approach. Section 5 discusses our results, and the last section concludes with some caveats and discusses the relevance of our findings to the climate adaptation discussions of managed-retreat programmes.

2. Data Sources and Processes

The healthcare system in New Zealand operates across three main levels: community, primary, and secondary services. Community services provide accessible support, often informal and without the need for a doctor's appointment, these are less well recorded, and typically deal with more routine services. The primary services are the typical entry point into the public healthcare system. Although patients can directly access secondary services, it is more common for referrals to come from primary services. In this study, mental health data are extracted from primary and secondary service records. We use mental health data records between 2009 and 2018 as this time period is the common overlap between the different administrative sources we use. We use these data to test our hypothesis, that being in the RRZ at the time of the Christchurch earthquakes may be associated with a later change in mental health, expressed as anxiety, mood, depression, or eating disorders.

The data come from 3 sources: (1) The pharmaceutical collection contains claim and payment information from community pharmacies for subsidised dispensing of prescriptions. It is not possible to identify if people actually take the medicines, but our aim is to identify the onset of symptoms that generated the prescription,

not the efficacy of treatment. Unsubsidised dispensing is not included in this data and is unknowable. This pharmaceutical data has been linked to the IDI data by the Ministry of Health and PHARMAC since 2005. (2) National minimum dataset (NMDS) includes reported discharges from hospitals for inpatients and day patients from all of the publicly funded hospitals (by far most people in NZ are treated in the public hospital system). Private funded hospital events have been excluded from this dataset in the IDI because not all privately funded hospitals in New Zealand submit their data to the Ministry of Health continuously. For our study, NMDS data collected from July 2008 onwards were used. (3) Programme for the Integration of Mental Health Data (PRIMHD) includes specialist services from all publicly funded service providers (thus excluding privately funded services). PRIMHD is a set of national mental health data collected by a Ministry of Health on service use and diagnoses. Data is collected from District Health Boards (BHDs) and non-governmental organizations (NGOs) that provide government-funded mental health and addictions information to health consumers in New Zealand. PRIMHD data are available in the IDI from July 2008.

In this study, mental health indicators include anxiety, mood, depression, eating disorder, and substance abuse. We do not examine indicators that may not be caused by relocation but are more likely to be genetically determined, such as dementia, and attention-deficit hyperactivity disorder. Mental health levels were categorized into two groups: less severe cases comprised individuals who visited a general practice doctor (GP) and received a prescription, as indicated by pharmaceutical data, while severe cases included individuals who were hospitalized or utilized publicly-funded specialized services, as indicated by a combination of the NMDS and PRIMHD data. For individuals with less severe mental health issues, 98% were associated with mood disorders, while the remaining 2% were linked to substance abuse. In the severe level group, eating disorders represented less than 3%, whereas both mood disorders and substance abuse accounted for almost 50% of cases each in this group.

The IDI locates each observed individual to a meshblock.[4] Those meshblocks—essentially small neighbourhoods –that were classified as Red Zone were used to identify the list of individuals who resided in these areas between March 2010 and June 2011 and were therefore subject to the mandatory relocation requirement. Of the 348 meshblocks that were part of the RRZ programme, we also distinguished between meshblocks that were wholly within the Red Zone (261 meshblocks) and those where the boundary of the Red Zone passed through the meshblock thus making identifying whether an individual was subject to a relocation mandate less accurate (87 meshblocks). We used these individuals residing in the 261 meshblocks wholly within the RRZ as our 'treatment' group. The controls were identified from all the individuals residing elsewhere in the Territorial Authorities of Christchurch and Waimakariri (but excluding the 87 RRZ boundary meshblocks). Children aged 0-15 years were excluded due to their low incidence of mental health issues and their reliance on parental decisions regarding access to medical services (see also Beaglehole et al., 2020).

Next, we linked all the regions meshblocks to earthquake housing damage maps (based on residential public insurance claims – see Nguyen and Noy, 2020). This allows us to identify the degree of damage experienced in each individual's meshblock, and thus restrict our control group only to those individuals that experienced similar earthquake intensities and housing damage levels to the RRZ residents. We categorised

the damage experienced in each meshblock throughout Christchurch into three damage groups. In the Red Zone, these were: for group A – light damage (<6%; 12 meshblocks); group B – moderate damage: (6%-14%; 93 meshblocks), group C – severe damage (>=15%; 159 meshblocks). As there were few people who resided in group A meshblocks in the RRZ, we excluded them from both the treatment and control group.

By the end of 2011, 77.3% of the former RRZ residents were still in the area, and only 22.4% were there still be end of 2012, and very few were still there by the end of 2013. Among the RRZ movers, 82% relocated within the Canterbury-Christchurch region and most of the others relocated to other regions in New Zealand. Moreover, 66% relocated within the same territorial authority (Christchurch City or the adjacent Waimakariri district, depending on the location of their RRZ meshblock). For those RRZ people who moved further away, the top three destination regions were, Otago, Auckland, and Wellington – these are the neighbouring region to the south of Canterbury, and the two largest cities in New Zealand, respectively (see Hoang and Noy, 2023).

We combined the lists of individuals from the treatment and control groups with the pharmaceutical data, NMDS, and PRIMHD data to compile all mental health treatment events and their corresponding dates from January 2009 to December 2018. The 2009 start date was based on data availability and quality. Subsequently, we segmented the dataset into two distinct groups: Group 1 - Individuals without any mental health records from January 2009 to June 30, 2011 (prior to the introduction of the RRZ program). Group 2 - Individuals with a pre-RRZ mental health diagnosis between January 2009 and June 30, 2011.

We then conducted a longitudinal follow-up to observe whether new instances of mental health issues emerged following the implementation of the RRZ program among those previously unaffected and whether existing mental health conditions occurred again among those with prior records. The specific questions we aim to investigate are these:

(H1) Did involuntary relocation, because a person resides in the RRZ, increased the likelihood of a new mental health diagnosis for these RRZ individuals, when compared to individuals who also experienced the damaging earthquake but were not mandated to move?

(H2) Did involuntary relocation increased the frequency of mental health treatments for RRZ individuals who had already had observable mental health problems before the earthquake, when compared to similar individuals who also had pre-RRZ mental health problems, had experienced the damaging earthquake, but were not mandated to move?

3. Descriptive statistics of the data

Table 1 describes the statistics for the data we use. The RRZ residents and the control group share a similar average age. The age distribution between the two groups is also very similar, with 19% aged 16-24, 37% aged 25-44, and 43% aged over 44 years old. Within the RRZ group, 52% are women, 11% are Māori, and 64% were enrolled in tertiary education at some point. Similarly, the control group comprises 51% women, 9% Māori, and 63% with tertiary education qualifications. We conducted a balance test to assess the variation in characteristics between the red zone (RRZ) and control groups (column 5). There are no systematic differences in age, gender, the final year they attended school, frequency of visiting a GP for mental health

concerns, or total income in the first half of 2011. While ethnicity, tertiary education enrolment, pre-existing mental health conditions (from January 1, 2009 to June 30, 2011), and qualification level exhibit statistically significant differences between the groups, these variations are very small.

Table 1. Descriptive Statistics.

Variables	Control		Redzone		Balance tests
	N	Mean or % (SD)	N	Mean or % (SD)	
	(1)	(2)	(3)	(4)	(5)
Age		44 (19)		43 (18)	F = 1.06
Age group					$\chi2 = 14.34^{***}$
16 - 24	20,727	19%	1,464	19%	
25 - 44	40,191	37%	2,907	37%	
45 - 64	30,468	28%	2,334	29%	
65+	16,743	15%	1,119	14%	
Gender					$\chi2 = 2.85$
Men	52,659	49%	3,729	48%	
Women	55,473	51%	4,092	52%	
Tertiary education enrolment					$\chi2 = 7.05^{***}$
No	39,918	37 %	2,769	36%	
Yes	68,214	63 %	5,052	64%	
Last school year	62,052	1992 (15)	4,662	1992 (15)	F = 1.92
Ethnicity					$\chi2 = 29.31^{***}$
Non- Māori	97,956	91%	6,939	89%	
Māori	10,176	9%	882	11%	
Pre-existing less severe mental disorder					$\chi2 = 23.43^{***}$
No	91,932	85%	6,489	83%	
Yes	16,203	15%	1,332	17%	
Average number of times visiting a GP		0.52 (3.8)		0.57 (3.7)	F = 1.43
Pre-existing severe mental disorder					$\chi2 = 17.90^{***}$
No	97,605	90.3%	6,942	88.8%	
Yes	10,524	9.7%	879	11.2%	
Total income ($NZD)	93,525	14,127 (17,505)	7,068	13,970 (12,111)	F = 0.67

Statistical significance: * p<0.1; ** p<0.05; *** p<0.01. SD refers to the standard deviation. Age is in 2011. Total income is stated in 2018 NZD, the number of times visiting a GP was determined during the first 6 months of 2011; Pre-existing mental disorders were identified from January 1st, 2009, to June 30th, 2011. Less severe cases were identified as those who visited a GP, while severe cases were identified as those who were admitted to the hospital or used specialist services.

During Jan 2009 to June 2011- the two and a half years before the RRZ program was announced, we identified the individuals who were treated for mental health. This group includes about 10% of the entire cohort in both the control and red zone groups that had pre-existing but moderate mental health issues, while only about 2% had been facing pre-existing severe mental health challenges.

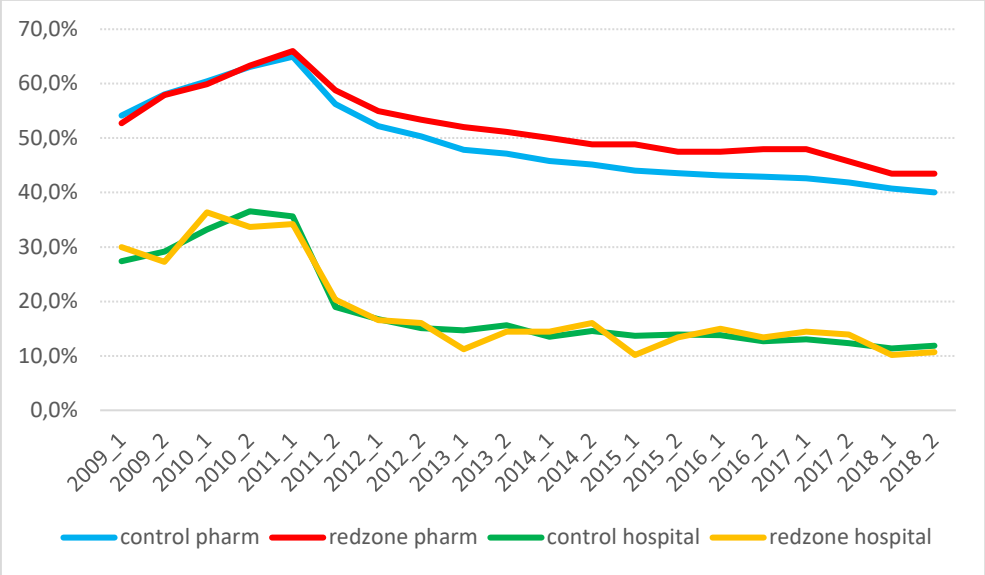

Fig. 1. Rates of moderate mental health treatments for individuals with pre-existing conditions

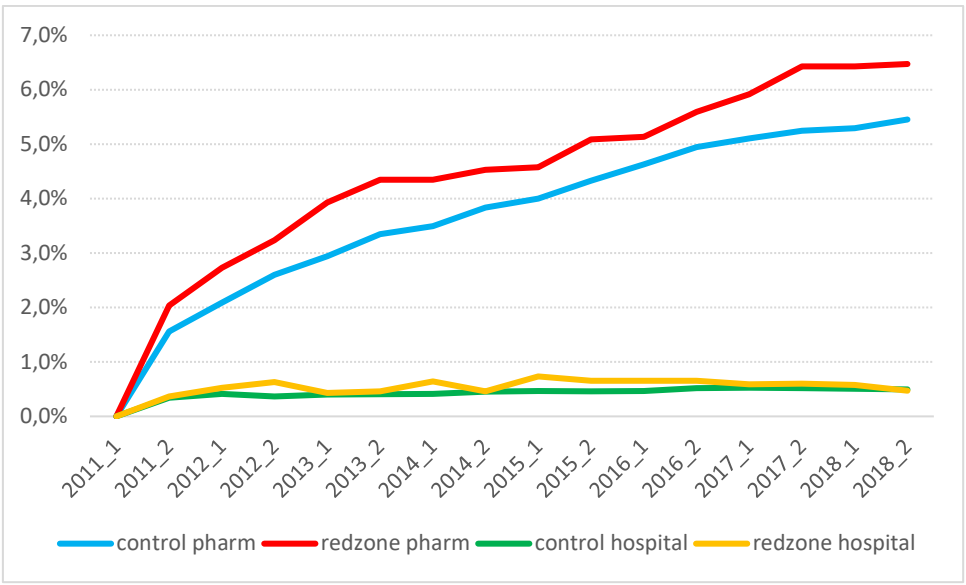

Fig. 2. Rates of moderate mental health disorders among individuals without pre-existing conditions

Figure 1 presents the percentages of individuals with pre-existing mental health conditions. The rates increased from January 2009 to the middle of 2011 in both groups. Subsequently, the rates began to decline. However, the rates for the RRZ residents decreased at a slower pace compared to their counterparts in the control group. Figure 2 illustrates the percentages of individuals without pre-existing severe mental health conditions. The rates of mental health issues among individuals in the RRZ are higher than those in the control group. They increased rapidly every 6 months in the two years after relocation (until the end of 2013) before stabilizing during 2014-2015, suggesting that relocation may have had a more severe effects in the shorteer term.

Overall, the numbers of individuals admitted to hospitals or those utilizing specialist services are small. We note that the number of individuals with pre-existing severe mental health issues accounted for approximately 2% of the entire cohort in both the control and red zone groups. There are consequently instances where the rates in the RRZ group fell below those of the control group, but these data should be interpreted with caution due to the small sample size.

4. Econometric methodology

Our approach to assessing the impact of involuntary relocation on mental health, including both the occurrence and severity of issues, at the individual level, focuses on comparing RRZ residents to their neighbours (identified as the control group in section 2) after the introduction of the RRZ program at the end of June 2011 (a difference-in-difference strategy).

Given that the presence of mental health issues during a given period is a binary outcome at the individual level, we employ a logistic regression model. However, since the severity of issues—defined by the frequency of visits to a GP for less severe conditions, or admissions to the hospital, or utilization of special services for severe conditions—is represented by counts, we utilize a Poisson regression model. We estimate the following:

$$Y_{it}^{*} = \beta_0 + \beta_1\, Treat_i + \beta_2\, Post_t + \beta_3\, Treat_i * Post_t + \beta_4 Demographic_{it} + v_t + e_i + u_{it} \quad (1)$$

Where: Y_{it}^{*} denotes whether person *i* had received a medical intervention for a mental health issue (prescription drugs or specialist services) in every half-year period *t*, or it denotes the number of medical interventions for mental health events for person *i* in period *t*. $Treat_i$ is an indicator variable equal to 1 if person *i* lived in the RRZ areas before June 2011. $Post_t$ is a dummy variable equal to 1 if periods from July 2011 to Dec 2018. $Demographic_{it}$ includes age, gender, highest education level, and ethnicity. As the RRZ program was announced at the end of June 2011, we combine data for each 6 months period (January-June and July-December); we include time fixed effect (v_t) for each 6-months period, and individual fixed effect (e_i) to account for time-invariant unobservable factors. Since in this type of longitudinal data, the observations of the same person may be correlated over time, so are the error terms for each person (u_{it}). Our preferred specification, therefore, clusters standard errors at the individual level.[5]

The odds and incident rate ratios are defined as:

$$Odds = \frac{p}{1-\mathrm{p}} \quad (2)$$

where *p* is the probability of experiencing mental health issues; and 1-*p* is the probability of not experiencing mental health issues.

$$\text{Incident rate ratio } (IRR) = \frac{events}{person\ time} \quad (3)$$

where *events* refer to the number of visits to a GP for moderate mental health conditions. For severe mental health conditions, the number of admissions to the hospital or usage of specialist services are counted. *person time* refers to the number of 6 months periods.

We are interested in estimating the treatment effect of relocation, which we refer to as TE:

$$(TE) = \frac{\frac{Odds/IRR\,[mental\ health|redzone,postRRZ\ program]}{Odds/IRR\,[mental\ health|redzone,preRRZ\ program]}}{\frac{Odds/IRR\,[mental\ health|control,postRRZ\ program]}{Odds/IRR\,[mental\ health|redzone,preRRZ\ program]}} \quad (4)$$

We can calculate the mental health odds of people in the RRZ and the control group, before and after the implementation of the RRZ program, while adjusting our estimates for differences in various factors across people and periods. The difference-in-difference in equation (1) estimation give us the β_3= ln(TE). We thus report the exp (β_3) as the odds or IRRs of mental health for individuals living in RRZ areas relative to the odds or IRRs for individuals living in non RRZ areas before the earthquakes.

We initially estimate effects across all cohorts, then stratify into subgroups based on whether these individuals were with or without pre-existing mental health recent treatment. Subsequently, within each of these groups, we estimate effects for various demographic strata, including gender (men and women), age categories (16-24, 24-44, 45-64, and 65+), ethnicity (Māori and non-Māori), tertiary education (individual with and without tertiary enrolment), and housing damage levels.

5. Estimation results

Treatments for moderate mental health problems

We report the relocation effects separately for less severe mental health conditions and more severe ones. For each, we present the relocation effects on the likelihood of experiencing mental health problems estimated with a logit model (i.e., the extensive margin) and the intensity of mental health problems as measured by the number of treatments (i.e., the intensive margin). The latter are estimated using a Poisson model. For OR, a value greater than (less than) 1 indicates that the odds of experiencing a mental health issue for the RRZ group exceed (are below) those of the control group. An OR of exactly 1 indicates no difference in the likelihood of having a mental health issue between the RRZ and control groups. For the IRR, compared to the control group, the incidence rate (or the expected count) of visits to the GP or admission to the hospital for the RRZ group increases by the factor expressed by the IRR (if IRR>1), while values less than 1 indicate a decrease in the incidence rate.

All regression table results show the estimated treatment effect obtained from a separate regression for the relevant sample or sub-sample. Thus, the first row and first column in table 2 shows the impact of being an RRZ resident on the likelihood of obtaining prescription medication (for mental health issues) for the full sample. Thus, RRZ residents were 22% more likely to receive such prescription than similarly earthquake-affected other residents of Canterbury.

Table 2 (column 1) shows the result of the logistic OR regressions. Compared to their neighbors, RRZ residents were more likely to receive prescriptions for mental health problems. This was true especially for the elderly, non-Māori, and individuals who had no tertiary education. While both men and women, when

estimated separately, had an increase likelihood of being prescribed, the effect of being in the RRZ seems to be larger for men (this difference is statistically significant). Conversely, no effects were observed for individuals younger than 65, for Māori, and for those with tertiary education, or for those whose houses sustained less damage (group B).

Overall, RRZ residents had 22% higher odds (95% CI: 1.09-1.37) of experiencing mental health issues after relocation compared to those who didn't relocate. This adverse effect was observed for both women (18%) and men (30%). Most acutely, the RRZ elderly individuals were 2.5 times more likely to experience mental health issues after relocation when compared to elderly individuals in the other earthquake-affected areas.

Table 2. The likelihood of receiving moderate (pharmaceutical) mental health treatments

Variables	OR- Full sample	OR- Without previous mental health treatment	OR- With previous mental health treatment
	(1)	(2)	(3)
All observations	1.224****	1.465****	1.359****
	(3.46)	(6.43)	(4.13)
Women	1.180****	1.412****	1.363****
	(2.24)	(4.69)	(3.33)
Men	1.299***	1.468****	1.345**
	(2.73)	(3.74)	(2.41)
16-24	1.109	1.437***	1.239
	(0.81)	(3.20)	(1.41)
25-44	1.024	1.434****	1.113
	(0.26)	(3.66)	(0.98)
45-64	1.039	1.396**	1.023
	(0.34)	(2.42)	(0.16)
65+	2.499****	1.752****	3.809****
	(5.34)	(3.56)	(5.37)
Māori	0.891	1.098	0.821
	(-0.72)	(0.56)	(-1.04)
Non-Māori	1.272****	1.389****	1.449****
	(3.86)	(4.85)	(4.63)
Tertiary education	1.054	1.275****	1.166*
	(0.75)	(3.36)	(1.79)
No tertiary education	1.619****	1.731****	1.827****
	(4.52)	(4.73)	(4.18)
Damage group B	1.054	1.400***	1.238
	(0.47)	(2.84)	(1.50)
Damage group C	1.304****	1.379****	1.376****
	(3.57)	(4.07)	(3.37)

Statistical significance markers: * p<0.1; ** p<0.05; *** p<0.01; **** p<0.001; OR: odds ratio. Each observed coefficient is obtained from a separate regression.

In regression results reported in the supplementary appendix, we also performed regression analyses for different mental health prescription medications. Compared with those in the control groups, people in RRZ had a 23% higher likelihood to be treated for mood and anxiety and the difference was statistically significant (p<0.001). No statistically significant findings in substance use treatment were identified.

Table 2 (column 2-3) reports the separate estimation of the effects of relocation for individuals with and without previous mental health treatment records. Specifically, column 2 presents the findings for individuals who did not have a recent history of mental health treatments. Among this group, the elderly (75%) and those without tertiary education (73%) experienced the most significant adverse observable mental health problems from their forced relocation. Additionally, among individuals without a pre-earthquake recent history of mental health treatments, those residing in the RRZ areas during the time of the earthquake were associated with a 1.46 times higher likelihood of receiving mental health medications compared to the control group (statistically significant). This was true for both women (41%) and men (46%), but with no statistically significant differences between genders. The elderly (65+) demonstrated the highest significance, with a 75% higher likelihood compared to around a 40% higher likelihood for the younger age groups. Results for individuals with a recent history of mental health treatments are presented in column 3. These effects are similar to those observed for the entire cohort in column 1, as many of the treated individuals in the post-earthquake period had also received treatments before (see figures 1-2).

Our assessment of mental health problems intensity margin relies on the frequency of visits to a GP for mental health issues. As shown in Table 3, the Poisson regression results indicate that only the elderly group is impacted by relocation in terms of the frequency of mental health treatments. Specifically, on average from 2011 to 2018, RRZ's elderly individuals had 28% more mental-health-related visits to a GP compared to the control group.

Table 3. The frequency of receiving moderate (GP visits) mental health treatments

Variables	IRR- Full sample	IRR- Without previous mental health treatment	IRR- With previous mental health treatment
	(1)	(2)	(3)
All observations	1.037 (0.42)	1.136 (1.39)	1.045 (0.48)
Women	1.079 (0.74)	1.107 (0.98)	1.109 (0.89)
Men	0.962 (-0.26)	1.17 (0.98)	0.919 (-0.59)
16-24	1.150 (1.12)	1.128 (0.97)	1.105 (0.70)
25-44	0.932 (-0.75)	0.963 (-0.18)	0.966 (-0.38)
45-64	0.966 (-0.18)	1.365* (1.80)	0.949 (-0.25)
65+	1.289*** (2.86)	1.231 (1.41)	1.287*** (2.89)
Māori	0.712 (-0.93)	0.934 (-0.21)	0.738 (-0.86)
Non-Māori	1.079 (0.92)	1.16 (1.57)	1.079 (0.92)
Tertiary education	1.046 (0.38)	1.085 (0.63)	1.1 (0.72)
No Tertiary education	0.988 (-0.12)	1.217* (1.65)	0.94 (-0.58)

Damage group B	1.124 (0.47)	0.937 (-0.50)	1.231 (0.75)
Damage group C	0.966 (-0.44)	1.213 (1.62)	0.932 (-0.87)

Statistical significance markers: * p<0.1; ** p<0.05; *** p<0.01 ; **** p<0.001; IRR: Incidence rate ratio. Each observed coefficient is obtained from a separate regression.

Results from tables 2-3 indicate that the elderly are the most affected age group. Subsequently, we conducted regression analysis exclusively for the elderly to investigate the factors influencing their mental health (Table 4). For the elderly (age>65) being a woman, non-Māori, lacking tertiary education, and having severe damage to the house (group C) were the sub-groups most affected by relocation with a likelihood 2.7 times higher of experiencing mental health issues compared to the control group (Table 4, column 1). It is only for the elderly Māori that we did not observe a significant difference in the likelihood of experiencing mental health issues between the RRZ and the control groups.

Table 4. The likelihood and frequency of receiving treatment for the elderly.

Variables	OR- Likelihood	IRR- Frequency
	(1)	(2)
Women	2.730**** (4.60)	1.265** (2.30)
Men	2.194*** (2.85)	1.347* (1.70)
Māori	1.098 (0.14)	1.583** (2.03)
Non-Māori	2.526**** (5.34)	1.284*** (2.78)
Tertiary education	1.780* (1.66)	1.327* (1.83)
No Tertiary education	2.750**** (5.13)	1.278** (2.41)
Damage group B	2.171** (2.41)	1.388* (1.78)
Damage group C	2.597**** (4.36)	1.288** (2.26)

Statistical significance markers: * p<0.1; ** p<0.05; *** p<0.01; **** p<0.001. OR: odds ratio. IRR: Incidence rate ratio. Each observed coefficient is obtained from a separate regression.

In addition to the estimation of the average relocation effect over the post- relocated periods, we also are interested in the dynamic effects overtime, and therefore estimate our specifications for different points in time since July 2011. For this, we estimated an 'event study' specification, incorporating the interaction of treatment and time for each period. Fig. 3 presents the estimated dynamic impacts. It is obvious from this analysis that while the extensive-margin impact on the non-elderly is statistically significant, this is identified only through 2013. Much larger impacts are observed for the elderly, in both the extensive and intensive margins, and these persist until the end of our dataset at the end of 2018, more than 7 years after the earthquake, and at least 5 years after the forced relocation away from the RRZ areas.

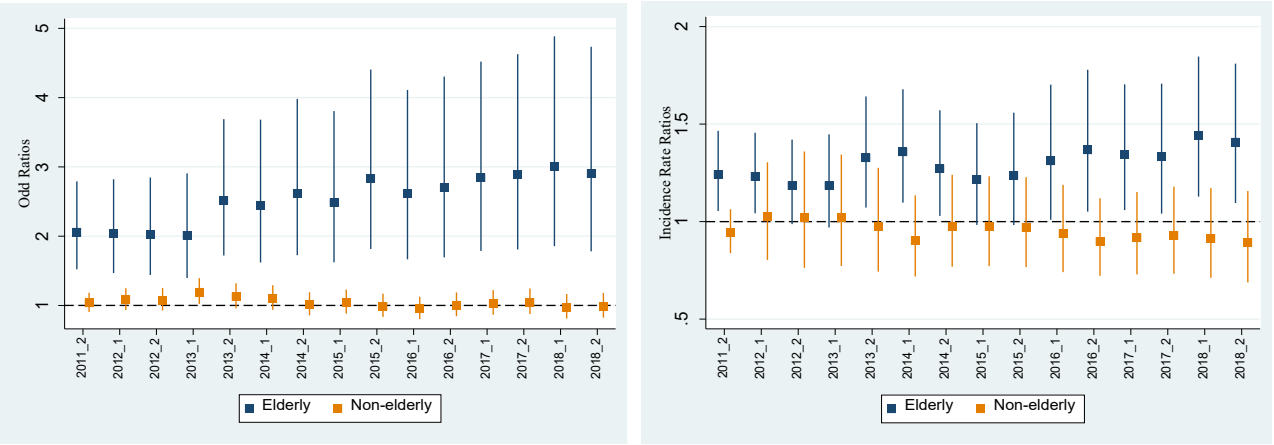

Fig. 3. The dynamic effects odds ratios (left panel) and incidence rate ratio (right panel)

Treatments for severe mental health problems

We estimate the likelihood of being treated for more severe mental health problems and the incidence rate ratios number of time which people visited the hospital or used specialist psychiatric services in Table 5. Overall, relocation did not significantly affect severe mental health treatments in terms of both likelihood and frequency. We do observe a weaker statistically significant effect for the elderly and individuals whose houses were in the less damaged group (group B), while no statistically significant effect was found for other groups. Additional analyses were done on the rate ratios for people with or without existing mental health before (column 3 and 4). In these we do observe some statistically significant impact on women and the young (aged 16-24) for people without previous (pre-earthquake) mental health treatments. Overall, we note that many fewer people were treated in the hospitals or in specialist services for mental health problems (in our definition – this is 'severe'), so the statistical power of our analysis is much reduced.

Table 5. The likelihood and frequency of receiving treatment for severe mental health problems

Variable	OR- Full sample	IRR- Full sample	IRR- Without previous mental health treatment	IRR- With previous mental health treatment
	(1)	(2)	(1)	(2)
All observations	1.108 (1.27)	1.180 (1.28)	1.470*** (2.61)	1.076 (0.58)
Women	1.038 (0.32)	1.205 (1.12)	1.685** (2.55)	1.085 (0.48)
Men	1.179 (1.45)	1.143 (0.68)	1.261 (1.11)	1.143 (0.68)
16-24	1.113 (0.55)	1.378 (0.99)	2.032** (2.27)	1.075 (0.21)
25-44	0.926 (-0.60)	1.037 (0.19)	1.35 (1.25)	1.026 (0.14)
45-64	1.083 (0.52)	1.193 (0.89)	1.359 (1.16)	1.073 (0.36)
65+	1.554** (2.03)	1.662* (1.82)	1.229 (1.09)	1.662* (1.82)
Māori	1.137	0.920	1.274	0.726

Variable	OR- Full sample	IRR- Full sample	IRR- Without previous mental health treatment	IRR- With previous mental health treatment
	(1)	(2)	(1)	(2)
	(0.68)	(-0.28)	(0.72)	(-1.31)
Non-Māori	1.098 (1.05)	1.254 (1.58)	1.480** (2.43)	1.175 (1.12)
Tertiary education	0.964 (-0.36)	1.206 (1.29)	1.378* (1.69)	1.161 (0.97)
No tertiary education	1.386** (2.44)	1.129 (0.53)	1.681** (2.28)	0.932 (-0.35)
Damage B	1.507*** (2.66)	1.774** (2.52)	1.102 (0.56)	0.866 (-0.81)
Damage C	0.981 (-0.19)	0.924 (-0.47)	2.536*** (3.47)	1.546** (2.12)

Statistical significance markers: * p<0.1; ** p<0.05; *** p<0.01; **** p<0.001; OR: odds ratio. IRR: Incidence rate ratio. Each observed coefficient is obtained from a separate regression.

6. Discussion and Conclusion

Several studies have documented elevated levels of mental health issues among populations that relocate. In most cases, however, the selection to relocate is a combination of external pressures combined with household choice. It is thus difficult to causally ascribe the mental health challenges to the move. This study contributes a causal identification, as it uses a 'natural experiment' – a relocation that was mandated (forced) and was, to a large extent, randomly allocated (in terms of households' characteristics) to different neighbourhoods in the city of Christchurch. As we use individual-administrative data for the entirety of the population residing in the city, we are able to investigate the impact of relocation on different sub-populations and the dynamic impacts on these sub-populations over time.

Specifically, we look at the aftermath of the Christchurch 2011 earthquake and differentiate between those individuals who were mandated to relocate under the RRZ 'managed retreat' programme, and other people in Christchurch who were similarly affected by the earthquake but were not forced to relocate in the earthquake's aftermath (though their houses may have suffered similar amounts of damage). By linking mental health treatment services to individual demographic characteristics, we were able to isolate the impact of relocation from other confounding factors.

We found a statistically significant increase in the likelihood and frequency of receiving treatment for moderate mental health problems among individuals compelled to relocate, when compared to other residents of the city whose houses were not situated in the RRZ areas and were thus not compelled to relocate. This effect persisted from July 2011 to December 2013, and remained significant across all the examined period to 2018, for the elderly. Thus, we identified both short-term and long-term adverse mental health impacts. While a prior study—Hogg (2015), using different methodology and different data—primarily examined short-term effects after the earthquake, our study provides robust evidence confirming the enduring adverse impact of the relocation, and identifies this enduring impact specifically for the elderly.

However, even though the identified relocation effects were statistically significant, the numbers of new mental health patients remained small. This is possible due to the strong community cohesion observed in many post-disaster situations, as 82% of relocations occurred within the Canterbury region.[6] Additionally, generous government compensation were provided to RRZ residents, so relocation was unlikely to involve very significant material hardship; even though it did lead to some small declines in earned income (Hoang and Noy, 2023).

Limitations of the available data and other caveats

Some limitations of our study are worth noting. First, we had no access to the relocation contracts that people signed and the amount of compensation they received – this amount was mostly determined by the value of their house, if they owned their residence (Nguyen, 2020). Renters, in contrast, did not receive any assistance. Our focus is on the mental health impact of people when they are forced to relocate, but it is conceivable that the impact may be very different for renters and homeowners, and for owners according to the amount of compensation received and the terms in which this compensation is provided.[7] Unfortunately, with our data, we cannot identify these differences and their relevance to mental health.

Furthermore, there is a large literature that ties social capital (bonding, bridging, and linking social connections – see Aldrich, 2012) to post-disaster economic outcomes. Presumably, the loss of social capital may be very important for mental health, since at least in this case neighbourhoods were scattered because of the RRZ policy and thus at least some social ties were severed. It is likely that the breakdown of social ties, especially of significance to the elderly, is the mechanism that explains our results. However, our data does not allow us to measure social capital directly, so we have no way of verifying this conjecture.

It is noteworthy that the indigenous people of Aotearoa New Zealand, the Māori, were not observed to experience a statistically significant impact with respect to both the frequency and likelihood of their interactions with mental health treatment system post-relocation. One possible explanation could be the lower likelihood of Māori to seek or to receive treatment for mental health problems compared to non-Māori more generally. Less access for Māori for many types of health services has been documented in many different contexts and involve several possible reasons. The most common explanation focuses on the documented distrust in the health system among Māori arising out of the different (and often inferior) treatment historically provided to Māori by the public health system. This points to a larger problem with our data. What we observe is not mental health issues, but their treatment. In as much as many mental health challenges go untreated, we are unable to capture and investigate their dynamic incidence and their connections to mandated relocation.

The relevance for climate-change induced managed retreat programmes

From a policy perspective, the RRZ program was a ‘managed retreat’ program, not dissimilar to such programs that are generated by the changing intensity of extreme weather events due to climate change. Agyeman et al. (2009) argue that “if future policies and plans for managed retreat are to be implemented

successfully, a great deal of further work is required since….they have neglected important psychological, symbolic, and particularly emotional aspects of healthy human habitats…and that a failure to address this crucial qualitative aspect of relocation may fundamentally undermine wider policy and planning initiatives on adaptation to climate change." (p. 509).

The importance of mental health as a component of the process of managed retreat—an important component of societies' adaptation strategies to climatic change—has been recognised already at least 15 years ago, but remarkably we have not found any attempt to quantify whether Agyeman et al. (2009)'s concern about the mental health consequences of managed retreat are indeed material and relevant – see for example the review in Solecki and Friedman (2021). In short, 'how big is this psychological challenge?' is an important question, as without it, it is difficult to see how a full consideration of the costs and benefits of a decision to relocate in a program of managed retreat can be appropriately weighed.

In the context of climate change, two types of managed retreat programmes have generally been implemented: Slow and deliberate pre-disaster anticipatory retreat, and post-disaster retreat that is initiated after a catastrophic event led to physical destruction and increased saliency of the risk. The first is considered the gold standard in the managed retreat literature, but one that is much more difficult and costly to implement, In contrast, post-disaster managed retreat, is socially cheaper as the destroyed homes need to be reconstructed anyway (somewhere). Post disaster programmes are also easier to implement as the increased salience of the risk makes it politically less fraught (Arnold et al., 2023). The RRZ is essentially an example of a post-disaster managed retreat program, and that is reflected in the (relatively) easy acceptance it received from the affected communities..

The policy literature has suggested that more deliberate and carefully planned retreats are easier psychologically (e.g., Dundon and Abkowitz, 2021). However, this hypothesis has never been tested in practice, and had just been assumed to be true (Dannenberg et al., 2019). We are unsure if it is true, but our investigation may be seen as a first step in constructing an informed answer to this question: Would the same kind of stress caused by 'place detachment' manifest in an anticipatory relocation as it did in a post-disaster relocation of the type we investigated?

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[1] The detailes about the exact government offer are available in Hoang and Noy (2020).
[2] By April 2015, approximately 7,800 property owners (over 96 percent of the eligible group) had accepted the government's offer to sell their properties to the Crown, most had already settled their claimed compensation, and nearly all had already relocated.
[3] For a pertinent example on the post-disaster mental health prevalence among Japanese survivors of the 2011 Great East Japan Earthquake see Hikichi et al. (2017 & 2021).
[4] Meshblocks are the smallest geographically unit identified by Statistics NZ. They are like Census tracts in the US context, but significanly smaller (about 100 people on average, per meshblock).
[5] In STATA, we use the xtlogit command to run the fixed effects logistic regression model for panel data when the outcome variable is binary, and xtpoison command to run the fixed effects regression model when the outcome variable is a count variable.
[6] For details about the destinations of those relocated, see Hoang and Noy (2022). For examples for this general observation about the strength of social capital after disasters, see Solnit (2010).
[7] For details about these contracts, see Nguyen (2020). For details about the importance of the contractual details about people's wellbeing in the RRZ case, see Hoang and Noy (2020).