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Abstract

Aotearoa New Zealand is highly vulnerable to extratropical cyclones because of its unique location in the midlatitude south pacific region. This study empirically investigates the impact of the extratropical cyclones on individual income, combining the data from Statistics New Zealand's Integrated Data Infrastructure (IDI) and the weather-related insurance claims data from the Earthquake Commission. Our sample covers the administrative longitudinal panel data of all the IRD registered individual taxpayers between 2010 and 2019. We estimate a set of panel regressions with individual and time-fixed effects to assess the impact of extratropical cyclones on the affected individual's annual income. We find that income from salaries and wages is negatively affected by the cyclones across various specifications. Extratropical cyclones also negatively affect the total individual income from wages and salaries, benefit and compensation, and sole tradership. However, we have limited success in identifying individual characteristics influencing the affected people's income level in our study.

Keywords: Extratropical Cyclone; Disaster Insurance; Earthquake Commission; New Zealand

JEL: Q54

1. INTRODUCTION

Aotearoa New Zealand is located in the Southwest Pacific with a maritime and midlatitude climate. During the last decade, it has been repeatedly affected by extratropical cyclones. These cyclones produce mass rainfall and strong winds that also generate storm surges and lead to flood events (Lorrey et al., 2014). Most of the damage caused by these cyclones is to property and to horizontal infrastructure (e.g., roads and electricity networks). For example, an extensive slope failure occurred across the Tasman District by extratropical cyclone Gita in 2018, leading to significant damage and closure to State Highway 60 (Prasad & Fenton, 2020). The NIWA (2021) historical weather events catalogue maintains a record of all extratropical cyclones that occurred in New Zealand (NZ). Among these cyclones, the most destructive ones were: Gisele (1968), Bola (1988), Fergus (1996), Drena (1997), Ivy (2004), Debbie (2017), Cook (2017), Fehi (2018), and Gita (2018).

A very small number of existing empirical studies analyze the impacts of extratropical cyclones on the economy. In most cases, the overall cost of extratropical cyclones is assessed at a national or aggregate level. Local or individual-level impacts of extratropical cyclones remain under-studied. The micro-level analysis we describe here enables us to study the heterogeneity of the effects of extratropical cyclones on individual incomes.

This study utilizes administrative individual-level panel data from Statistics NZ's Integrated Data Infrastructure (IDI), matched with weather related-insurance claims data from the Earthquake Commission (EQC). We use this data to analyze the impacts of extratropical cyclones on individual income. We ask: What were the effects of extratropical cyclones on the different types of incomes earned by cyclone-affected individuals in New Zealand? We examine individual earnings from wages and salaries, benefits, self-employment, and income

from all other sources. We use a fixed-effect panel regression model with annual income data for all individuals in New Zealand.

The rest of the paper is structured as follows: Section 2 provides a brief description of the existing literature on extratropical cyclones and their impacts in high-income countries. Section 3 details the data sources and the empirical models used. Section 4 presents the results, and Section 5 concludes with further observations.

2 THE LITERATURE

A cyclone is a weather system where winds circulate a central low-pressure atmospheric area. There are various types of cyclones depending on their characteristics and location, such as tropical cyclones, extratropical cyclones, and tornadoes. Cyclones are the world's costliest natural weather disaster in terms of financial destruction (Ginis, 2021). Extratropical cyclones are also known as mid-latitude cyclones (Chang et al., 2002; Raible et al., 2021). These weather systems bring a wide range of weather variability, including massive precipitation as well as strong winds, and can cause extensive socioeconomic damage (Browning, 2004; Catto et al., 2012; Hawcroft et al., 2012; Pfahl & Wernli, 2012). Sometimes an extratropical cyclone is a tropical cyclone that moves into the midlatitude regions. This is particularly common in the West Pacific and the North Atlantic Oceans (Ginis, 2021). Through this transformation, tropical cyclones change their original structure and characteristics and turn into cold-cored systems. This transformation generates a storm with strong winds and intense rainfall, though the rainfall, on average, is still not as intense as that produced by tropical cyclones (Bieli et al., 2020; Evans et al., 2017; Frame et al., 2017; Jones et al., 2003). Most coastal high-income

countries are situated in the mid-latitude regions and several are thus exposed to extratropical cyclones.

Extratropical Cyclone in the United States

Hurricane Sandy, one of the most destructive extra-tropical cyclones in the history of the United States (US), hit the North Eastern seaboard on 29th October 2012. Sandy affected 24 states with record-level storm surges in New Jersey, New York, and Connecticut (Babson et al., 2020). Using business micro-datasets on the establishment, business, employment, sales revenue, and property characteristics, Meltzer et al. (2021) identified the impact of Sandy-induced floods on New York City retail business. They found that retail businesses dependent on local customers faced the most adverse hit to their revenue. After Sandy, retail businesses in the higher inundation blocks experienced an 11 percent increase in the probability of closure relative to those located in less inundated areas. The revenue of the business establishments situated at the high-surge blocks declined by 9 percent compared with the business establishments located in the low-surge blocks, in the aftermath of the storm.

Petkova et al. (2018) used a household-level survey administered in New York City (NYC) to examine the factors influencing the long-term recovery of Sandy-affected residents. The authors concluded that social and economic factors, such as health status, displacement, and household income played a crucial role in recovery. They also found that many residents of NYC affected by Sandy did not recover three years after the storm. In a micro-level study on households at the Rockaway Peninsula of NYC, Subaiya et al. (2019) reported that the employment status of nearly one-third of households had changed due to the storm, resulting in job loss (44 percent) and loss of pay (40 percent).

Recently, Hurricane Ida, a category four hurricane, made landfall in Louisiana on August 29, 2021. Risk modelling projected that insured costs could be between USD (31-44) billion (Scism, 2021). It moved towards the northeast and caused devastating floods to New York, New Jersey, Pennsylvania, and Connecticut. The estimated flood-induced insured commercial and residential property damages in the US Northeast region could be between USD (5- 8) billion, while the insured loss was estimated to be USD (11 - 16) billion (Baird-Remba, 2021).

Extratropical Cyclone in Europe

European winter windstorms, typically generated by extratropical cyclone systems, are the second most damaging natural hazard after floods in Western and Central Europe. These mid-latitude windstorms generally form in the North Atlantic and can lead to large-scale disasters (Fink et al., 2009; Haas & Pinto, 2012; Karremann et al., 2014; Priestley et al., 2018; Schwierz et al., 2010; Sharkey et al., 2020). Europe has experienced these windstorms initiated from extratropical cyclones quite frequently (Goldman et al., 2014). Some of these major storms were Storm David/Friederike (January 2018), Xavier (December 2013), Xynthia (February 2010), Klaus (January 2009), Kyrill (January 2007), and Lothar (December 1999) (Gardiner et al., 2010; Insurancejournal, 2018).

Despite having a significant impact on European economies, these windstorms remain understudied (Koks & Haer, 2020). A few studies on household- or individual-level socioeconomic impacts of these windstorms in Europe using microdata or survey data are available in the current literature. A couple of studies only reported the national or regional level aggregated economic loss or damages. For instance, according to the French insurance association, windstorms Lothar (1999) and Martin (1999) caused a loss of 6.9 billion Euros, and Klaus (2009) resulted in a 1.7 billion Euro loss due to wind-related property loss in France

(Peiris & Hill, 2012). Some windstorms hit south-western Europe in the winter season of 2009-10. Among the windstorms, Xynthia (February 2010) affected numerous regions, including Portugal and Spain, and some parts of Belgium, France, and Germany. The total financial loss was estimated at EUR 3.6 billion (Liberato et al., 2013). In France, the storm's direct loss amounted to more than EUR 2.5 billion (Genovese & Przyluski, 2013). von Möllendorff and Hirschfeld (2016) used a German Socioeconomic Panel Study (SOEP) to estimate the welfare effects of extreme events, including the Elbe flood (in 2002) and the storm Kyrill (in 2007). They used individual-level panel data and found that both events were responsible for a small but significant decrease in self-reported individual life satisfaction. The storm effects were short-term, but the effects of the flood remained for much longer. Another extratropical cyclone, Katia, impacted the British Isles in September 2011, causing USD 157 million of damage (Anfuso et al., 2020).

Extratropical Cyclone in Japan

The location of Japan in the western North Pacific Ocean basin makes the country highly exposed to extratropical systems. More than fifty percent of the typhoons, including the costliest typhoons landing in Japan, have undergone extratropical transitioning (Joseph, 2016; Loridan et al., 2014). Some of the costliest typhoons that hit Japan in the last decades are Typhoon Hagibis (2019), Faxai (2019), Jebi (2018), Trami (2018), Songda (2004), Mireille (1991), Vicki (1998), Bart (1999), Flo (1990), Sarah (1986), and Vera/Ise Bay Typhoon (1959). These typhoons caused significant damage to property and infrastructure in the affected areas. Okubo and Strobl (2021) have examined the survival, and survivor performance of the firms located in the Ise Bay Typhoon affected Nagoya City in the Ise Bay region. They used historical unique firm-level data, and flood inundation maps to study the impacts of the heterogenous damage across firms. Their findings indicate that after the flood, the survival strength of retail

and wholesale firms was lower than the firms in the manufacturing sector. The research finding also concludes heterogenous firm performance across the sectors, such as increased capital growth in manufacturing sectors and decreased sales and capital growth in local flood-affected wholesale sectors. However, for the firms in the retail sectors, no regional spill-over effects were observed.

Extratropical Cyclones in New Zealand

The geographic location of New Zealand makes it vulnerable to tropical cyclones formed in the South Pacific. At least one out of ten tropical cyclones from the South Pacific hits New Zealand, mainly in February or March. The Meteorological Service of New Zealand Ltd (MetService) follows the Australian tropical cyclone intensity scale guidelines for categorizing these cyclones (Table 1 in the Appendix).

Several extratropical cyclones have passed over New Zealand in recent years and caused considerable property and infrastructure damage. In terms of insured loss, four notable recent extratropical cyclones were Cook (2017), Debbie (2017), Gita (2018), and Fehi (2018). The combined insured cost of these four events was nearly NZD 200 million, surpassing the combined loss from all the other cyclones after 1980 (Insurance Council of New Zealand, 2021). This paper focuses on these four cyclones; a description of these cyclones follows in the next section.

3 DATA & METHODOLOGY

Data Type and Source

The primary data source we use is Statistics New Zealand's Integrated Data Infrastructure (IDI). It includes all individuals in New Zealand who are registered with the Inland Revenue

(IRD) department (i.e., everyone who has declared any amount of income). Income from all types of activities is recorded in the annual IRD tax forms that are completed annually; this data is then linked to other unit records by Statistics NZ in the IDI. We consider tax years 2010 (April 2010-March 2011) to 2019 (April 2019-March 2020).

The New Zealand Historic Weather Events Catalogue (HWE) of the National Institute of Water and Atmospheric Research (NIWA) contains a comprehensive and detailed list of all extreme weather events in New Zealand (NIWA, 2021). The list includes a variety of weather events (extratropical cyclones, storms, floods, strong wind, heavy rain, and heavy snowfall) from 1996 to 2019, with the intensity of the events, their dates and the affected regional councils. Fifteen extratropical cyclones are included in this list (see Table 3 in Appendix). A total of six extratropical cyclones affected the country from 2010 to 2019. Four major extratropical cyclones hit the regions between 2017 and 2018. Extratropical cyclones Debbie (3rd April) and Cook (11th April) hit in 2017, and Extratropical cyclones Fehi (1st February) and Gita (20th February) struck in 2018. During our sample period, there were two other extratropical cyclones: Pam (15th March 2015) and Lusi (14th March 2014). According to the Insurance Council New Zealand, the total amount of private insurance claims from Pam and Lusi was NZD 5.8 million, and the number of weather-related insurance claims from the public insurer was very small. On the contrary, the total amount of private insurance claims from the extratropical cyclones Debbie, Cook, Fehi, and Gita reached nearly NZD 200 million, including 17,630 weather-related public insurance claims after the cyclones. Further details about the cyclones are found in Appendix Table 2. Hence, our study concentrates on evaluating the impact of these four extratropical cyclones that happened to affect New Zealand in 2017 and 2018 (see Figure 1 in the Appendix).

EQC Insurance Claims

The Earthquake Commission (EQC) is the government-owned hazards insurance provider for residential property. The EQC only covers land damage for flooding events or storms. It also covers buildings (and other appurtenant structures, retaining walls, etc.) for landslips (the only weather hazard that is fully covered), and the non-weather hazards like tsunamis, earthquakes, volcanic eruptions.

The EQC weather-related insurance claims dataset we use identifies each claim by the geographic location of damage in terms of geo-coordinates (rounded by 70m to protect privacy). We consider the claims that were made three days before and after the occurrence date of each extratropical cyclone to detect the cyclone-affected meshblocks (meshblocks vary in land area but typically contain 40-60 houses). We identify those meshblocks where at least two or more weather-related insurance claims were registered, and that are also located in the cyclone-affected region, as identified in the NIWA/MetService list of extreme weather events.

We identify 227 meshblocks (with at least two cyclone-related insurance claims), 98 meshblocks (with at least three claims), 51 meshblocks (at least four claims), 39 meshblocks (at least five claims), and 36 meshblocks (at least six claims) (see Figure 2 in the Appendix). Our main results are reported for the 'at least two claims' meshblock group.

Individual Income Data (IDI, Statistics New Zealand)

Individual-level income from different sources has been collected from annual tax filings which report income. According to Inland Revenue (IR) guidelines, an individual receiving more than NZD 200 a year (before tax) needs to file an income tax return before the end of the tax year. The income information of all tax filers, usually aged 15+, is available in the IDI.

Every individual is identified in terms of their residential address within a meshblock (to preserve anonymity, only the meshblock information is provided. Given the nature and characteristics of individual income types, we grouped income into four categories (further explanations of each income type are provided in Table 4 in the Appendix):

1. Wage & Salary: Total yearly earnings from all wages and salaries (WAS)
2. Benefit & Compensation: Includes the summation of earnings from ACC payments (ACC is the public insurer for accidents and disability payments) and benefits (BEN) provided by the Ministry of Social Development.
3. Self-employment: This category is composed of yearly earnings from sole proprietorships or enterprises.[1]
4. Wage, Benefit & Self-employment: This sums up the previous three categories.

The individual income is provided for each tax year, starting from 1st April to 31st March. The dates of the four extratropical cyclones we focus on, occurred in two calendar years (2017 to 2018), but conveniently they all fall within the 2017 tax year (1/4/2017 to 31/3/2018).

Estimation Methods

We assume that individual income is influenced by time-invariant factors including education, expertise or skills, and geographic location. Including individual fixed-effects can control for any time-invariant determinants of income. Besides, we also include time fixed-effects to control for time-varying effects that are common to the population being examined (such as the macroeconomic business cycle). We thus estimate the following equation:

[1] Four types of earnings from sole proprietorship are included. These earnings come from income received by the individuals from sole trades or self-employment net profits (S00), earnings from sole traders paying themselves a wage and salary (S01), earnings from sole traders paying themselves withholding payments (S02), and earnings from sole traders receiving rental income (S03).

$$Y_{it}^{d} = \sum_{c=2014}^{2019} \beta_c D_c + \lambda_t + \mu_i + \varepsilon_{it} \ldots . (1)$$

where Y_{it}^{d} is the income of individual *i*, in time *t* of category *d* (salary, self-employment, etc.). Here, the cyclone-affected meshblocks are denoted by *D*, while *c* denotes the year, so that the coefficient β_c denotes the income of individuals residing in the affected meshblock in the respective year *c* (2014-2016 before the cyclone, 2017 is the year of the cyclones, and 2018-2019 are the following two years). For instance, D_{2017} = 1 for individuals who lived in the cyclones affected meshblock in 2017 and D_{2014} = 1 for people who lived in a cyclone affected meshblock in 2017 times a dummy variable for the year 2014. λ_t is a vector of year dummies to capture the year fixed effects from 2010 to 2019. The μ_i represent individual fixed effects. The ε_{it} is an idiosyncratic error term (ε_{it}~i.i.d). We calculate clustered standard errors at the individual level, which are robust both to heteroskedasticity and to correlation over time for an individual (Stock & Watson, 2020). We estimated four regressions based on the four income categories using Equation 1 for meshblocks that have at least two insurance claims.

4 RESULTS AND DISCUSSION

Summary Statistics

Table 1 describes the mean, standard deviation, and number of observations of different individual income categories from the extratropical cyclone-affected meshblocks and control meshblocks in 2017 and 2018. Columns 1 and 3 summarize the individual income from the affected meshblocks of at least two weather-related insurance claims. Columns 2 and 4 summarize the remaining unaffected meshblocks. Comparing average yearly individual incomes between affected meshblocks and control meshblocks shows very little difference between the two domains. There is also clear evidence that individual annual average income from all categories except income from self-employment increased slightly from the tax year 2017 to 2018. Similar notation is also visible for the individual income within the affected meshblocks simultaneously (columns 1 and 3). A graphical presentation of the average income from the affected and non-affected meshblocks has been shown in Appendix Figure 3. Table 1 reveals that, on average, income from benefits and compensation was the lowest amount in the income categories.

Estimation Results

We begin this segment by presenting the regression results of the impact of extratropical cyclones on the different incomes of individuals in the affected meshblocks compared with the individuals' income from the non-affected meshblock. We show both the regression results using the absolute value and the standardized regression coefficients (mean 0, standard deviation 1 outcome). The reason for reporting standardized regression coefficients is to compare the strength of the impacts of explanatory variables on the dependent variable.

Impact of Extratropical Cyclone on Individual Income (At Least Two Weather-related Insurance Claims)

Table 2 shows regression results of the impact of extratropical cyclones on individual incomes in the affected meshblocks. From Columns 1 to 5, the estimated coefficients of the dummy variables are presented. In Column 1, the estimated coefficient of the dummy variable (D_{2017}) is negative and statistically significant at a 5 percent level, where the dependent variable is the individual annual income from wage and salary. It indicates that, by adjusting other time-invariant individual fixed effects, income from wages and salaries on average decreased by NZD 555 for the individuals in the extratropical cyclone-affected meshblocks relative to those who were not in the same meshblocks in 2017 (Column 1). The estimated coefficients before and after the cyclone year 2017 were statistically insignificant, implying no significant change in income during these years. On average, total economic loss due to extratropical cyclones in terms of wage and salary reached NZD 4.6 million in 2017 (Appendix Figure 4). The estimated coefficient from self-employment in Column 3 is positive and statistically significant in 2019. Although this income increase occurred two years after the cyclone events, the possible reason for increasing income from a self-employed job maybe that construction and rebuilding jobs increased in the affected area after cyclones and provided additional income opportunities for those employed in this sector. The regression coefficients in Column 4 (Wage, Benefit & Self-employment) was negative but statistically insignificant. A graphical representation of the regression coefficients is presented in Appendix Figure 5. From Figure 5, it is visible that income from wage and salary was positive on average before the cyclone, and it suddenly declined after the cyclone. The other income type follows the same trend except for self-employment.

Table 1: Summary Statistics (Individual Income)

	2017		2018	
	Affected by Extratropical Cyclone in 2017) (1)	**Control Meshblocks (2)**	**Affected by Extratropical Cyclone in 2017) (3)**	**Control Meshblocks (4)**
Wage & Salary				
Mean	31580.39	32248.83	33021.3	33432.93
Std. Dev.	41469.01	42825.84	41646.91	43969.11
Observations	8,295	2,095,032	8,739	2,189,967
Benefit & Compensation				
Mean	1603.34	1587.92	1610.37	1553.20
Std. Dev.	4925.11	5141.84	5009.12	5148.15
Observations	8,295	2,095,032	8,739	2,189,967
Self-employment				
Mean	2549.01	2425.94	2330.54	2422.69
Std. Dev.	19030.13	20049.09	16783.67	20424.52
Observations	8,295	2,095,032	8,739	2,189,967
Wage, Benefit & Self-employment				
Mean	35732.75	36262.7	36962.23	37408.84
Std. Dev.	43635.16	45336.36	43079.88	46577.47
Observations	8,295	2,095,032	8739	2,189,967

Note: Income values are expressed in New Zealand Dollars. The cyclone-affected meshblocks are based on at least two weather-related insurance claims.

Table 2: Impact of Extratropical Cyclone on Income at Individual Level

	Wage & Salary (1)	**Benefit & Compensation (2)**	**Self-employment (3)**	**Wage, Benefit & Self-employment (4)**
D_{2014}	245.3	7.662	26.25	279.2
	(189.8)	(38.16)	(112.1)	(205.1)
D_{2015}	38.99	-27.04	91.93	103.9
	(219.7)	(38.54)	(110.4)	(226.9)
D_{2016}	-209.2	-22.29	191.4	-40.06
	(239.1	(41.93)	(144.9)	(257.8)
$D_{2017}^{\dagger}$	-555.1**	-2.006	235.4	-321.8
	(247.0)	(40.48)	(158.0)	(273.7)
D_{2018}	-349.8	20.37	112.6	-216.8
	(251.1)	(41.02)	(133.3)	(267.5)
D_{2019}	-493.6	-38.51	416.3**	-115.8
	(304.2)	(44.51)	(187.0)	(330.6)
R^2 (within)	0.037	0.0002	0.002	0.039

R^2 (Between)	0.0178	0.0011	0.0011	0.0231
Number of individuals	2,379,936	2,379,936	2,379,936	2,379,936
Number of observations	19,332,492	19,332,492	19,332,492	19,332,492

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

We also examined the impact of the extratropical cyclone on individual incomes by changing the measurement unit of the income variables, more specifically using the standardizing regression equation using the Z-score. The estimated standardized regression coefficients are presented in Appendix Table 6. The estimated standardized coefficient of the dummy variable (D_{2017}) in Column 1 is negative and statistically significant. This result is consistent with the absolute value regression coefficient of the variable. Individuals from the extratropical cyclone-affected meshblocks experienced 0.014 standard deviations decrease in income from wage and salary than those who lived outside the affected meshblocks. On the other hand, income from self-employment is found to increase by 0.023 standard deviations in the affected area during the cyclone years. Before cyclones, income coefficients show no significant change. Figure 6 in the Appendix shows the graphical presentation of the standardized coefficients.

Impact of Extratropical Cyclone on Above-Median and Below-Median Individual Income

At Least Two Weather-related Insurance Claims from a Meshblock

We next examine whether the impact of extratropical cyclones on individual incomes is different for differing levels of income. Specifically, we divide the population into two groups - above-median and below-median income, based on the median income threshold for total income category for the individuals living in the cyclone-affected meshblocks in 2016. We can thus compare the evolution of below-median income individuals affected by the cyclones

compared to below-median income individuals unaffected by the event (and similarly for the above-median group). Table 3 and Table 4 present the regression results containing above-median and below-median income groups, respectively. The standardized regression results of the above-median income (Appendix Table 7) and below-median income (Appendix Table 8) groups are reported in the appendix.

Individuals who belong to above-median income groups experienced a negative shock on their earnings from wages and salaries in the cyclone year and the following consecutive year (Table 3). The regression results presented in Table 3 also provide evidence that earnings from Wage, Benefit, and Self-employment decreased from 2017 to 2019, although the income coefficients of 2017 are statistically insignificant. The results from the standardized regression provided in Appendix Table 7 indicate similar statistical evidence that the cyclones had a negative impact on income from wage and salary. However, the estimated coefficient of the dummy variable (D_{2017}) at Column 3 in Table 3 is positive and statistically significant. It indicates that cyclones had a positive impact on income from self-employment income for above-median income groups. On the other hand, there is a lack of sufficient statistical evidence to conclude the adverse effects of the cyclone on the below-median income groups. We found no statistically significant indication for any income category negatively affected by the cyclones (Table 4, Appendix Table 8).

Table 3: Impact of Extratropical Cyclone on Above-median Income at Individual level

	Wage & Salary (1)	**Benefit & Compensation (2)**	**Self-employment (3)**	**Wage, Benefit & Self-employment (4)**
D_{2014}	200.3	-60.66	-24.71	114.9
	(279.2)	(45.77)	(236.3)	(322.1)
D_{2015}	82.16	-80.54	-8.158	-6.542
	(315.6)	(59.47)	(207.8)	(324.8)

D_{2016}	-180.8	-54.44	269.4	34.16
	(335.7)	(51.34)	(238.2)	(345.8)
$D_{2017}^{\dagger}$	-518	-57.36	424.7*	-150.6
	(333.1)	(52.66)	(254.6)	(356.9)
D_{2018}	-355	36.05	181.8	-137.2
	(333.6)	(58.12)	(223.8)	(344.5)
D_{2019}	-552.3	-98.63	752.7**	101.8
	(426.8)	(67.11)	(303.5)	(434.4)
R^2 (within)	0.094	0.0004	0.0037	0.105
R^2 (between)	0.012	0.00	0.0007	0.015
Number of individuals	1,562,673	1,562,673	1,562,673	1,562,673
Number of observations	9,530,400	9,530,400	9,530,400	9,530,400

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income (above-median) from the tax year 2010-2019. The median income is calculated from total individual income from the extratropical cyclone-affected meshblocks in 2016. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 4: Impact of Extratropical Cyclone on Below-median Income at Individual level

	Wage & Salary (1)	**Benefit & Compensation (2)**	**Self-employment (3)**	**Wage, Benefit & Self-employment (4)**
D_{2014}	44.93	7.79	-5.12	47.61
	(78.61)	(44.76)	(51.1)	(91.57)
D_{2015}	-90.28	-13.21	-22.09	-125.6
	(81.97)	(51.79)	(52.02)	(97.58)
D_{2016}	34.54	2.70	6.02	43.26
	(82.82)	(55.29)	(52.52)	(100.0)
$D_{2017}^{\dagger}$	61.81	21.66	58.92	142.4
	(83.16)	(53.27)	(49.09)	(98.89)
D_{2018}	51.92	-0.481	35.78	87.22
	(80.63)	(51.86)	(47.55)	(96.66)
D_{2019}	37.03	-45.59	67.6	59.04
	(85.32)	(60.1)	(63.21)	(110.4)
R^2 (within)	0.0005	0.0006	0.0005	0.0012
R^2 (between)	0.0155	0.0023	0.000	0.0246
Number of individuals	1,865,736	1,865,736	1,865,736	1,865,736
Number of observations	9,802,092	9,802,092	9,802,092	9,802,092

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income (below-median) from the tax year 2010-2019. The median income is calculated from total individual income from the extratropical cyclone-affected meshblocks in 2016. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Impact of Extratropical Cyclone Across Different Groups

The effects of extreme weather events such as extratropical cyclones on human society vary across different social factors, including gender, education, and ethnicity. We have investigated the impact of extratropical cyclones on individuals in the affected meshblocks based on their sociodemographic characteristics. We have distinguished individuals based on gender, ethnicity, and highest educational qualification, as noted in the 2018 census data. Table 5 highlights the cyclone impacts on selected income of individual groups and while additional detailed analysis is provided in the Appendix.

Gender

We have estimated the impact of extratropical cyclones on incomes of males and females from the cyclone-affected meshblocks, compared with the same gender in the non-affected meshblocks. Table 5 shows that income coefficients of wage and salary for men have declined after the cyclone. On average, a male income earner experienced NZD 876 loss in income due to the extratropical cyclones in 2017. They also faced further income losses in 2018 and 2019. Income coefficients of self-employment are positive and significant between 2015 and 2017. The income increase in the pre-cyclone period does not provide strong evidence of the cyclone-induced positive effect on self-employment income after the cyclones period. The income from other categories exhibits no statistical change before and after the cycle (Appendix Table 9) for either gender. Besides, we found no statistical evidence of decreasing income for females after the cyclones (Appendix Table 10).

Table 5: Impact of Extratropical Cyclone on Selected Individual Groups

	Male		Female	
	Wage & Salary (1)	**Self-employment (3)**	**Wage & Salary (1)**	**Self-employment (3)**
D_{2014}	259.7	158.8	211.0	-31.99
	(303.2)	(217.1)	(226.4)	(92.18)
D_{2015}	-102.8	416.2**	189.2	-142.1
	(345.1)	(203.2)	(267.1)	(105.5)
D_{2016}	-491.3	517.5**	116.8	-127.5
	(387.7)	(254.5)	(278.5)	(139.8)
$D_{2017}^{\dagger}$	-876.2**	613.5**	-201.9	-148.1
	(393.6)	(281.5)	(296.4)	(145.3)
D_{2018}	-780.8**	342.3	139.6	-110.4
	(392.7)	(234.8)	(313.7)	(129.2)
D_{2019}	-1,022**	968.1***	59.16	-150.2
	(483.7)	(331.6)	(363.6)	(174.1)
R^2 (within)	0.038	0.0017	0.039	0.0024
R^2 (between)	0.0193	0.0017	0.0201	0.0007
Number of individuals	1,167,486	1,167,486	1,212,450	1,212,450
Number of observations	9,536,529	9,536,529	9,795,960	9,795,960

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Ethnicity

We identified individuals based on ethnicities (European, Maori, Pacific, Asian, and Middle East, Latin American and Africa - MELAA). The estimated regression results provide statistical evidence that Europeans incurred NZD 513 loss in income from wage and salary due to the 2017 cyclones (Appendix Table 11). The estimated income coefficients from other sources of income show no statistical change for Europeans. The income coefficients are also negative for Maori in 2017 and the preceding year (Appendix Table 12). It is unclear whether the decrease in income in the cyclone year is due to the impact of cyclones or the influence from the previous year. In the rest of the ethnic communities, Pacific, Asian, and MELAA, we found no statistical evidence for any negative impacts of the cyclones on incomes (Appendix Table 13-15).

Education

Based on the highest educational qualification achieved, we categorized the individuals according to the Ministry of Education qualification levels: tertiary education certificates (level 1-4), diplomas (level 5-6), bachelor degree (level 7), and post-bachelor (graduate) education (level 8-10). The estimated regression coefficients are presented in Appendix Table 16-20. We found that income from wage, salary and benefits, and the total income of people with no tertiary education at all were negatively affected by the extratropical cyclones in 2017 (Appendix Table 16). In addition, the self-employment income of individuals with post-bachelor qualifications increased by NZD 930 in 2017 (Appendix Table 20). For the rest of the educational groups, we found no evidence of any effects of cyclones on incomes.

5 CONCLUDING REMARKS

This study has examined the impacts of extratropical cyclones on individual incomes in the cyclone-affected regions by using administrative (inland revenue department) annual income and a panel regression approach (with individual and time fixed effects). We match this income data with weather-related insurance claims from the affected meshblocks, we have investigated the economic impacts of extratropical cyclones at a micro-level.

Four large extratropical cyclones hit various parts of New Zealand between 2017 and 2018. Some regions were affected by more than two cyclones during the periods. These extratropical cyclones brought significant economic loss and damages to individuals residing in the areas. Our estimated results confirm that individual income from wages and salaries was negatively affected by the cyclones in the regions affected compared with the non-affected areas. In addition, we have also no found statistical evidence that individuals in both above-median

income groups and below-median income are adversely affected by the cyclones. This study is the first endeavor to use administrative individual-level panel income data to assess the cyclone impact in New Zealand. The findings of the paper also give concrete evidence of the microlevel socioeconomic impact of the extratropical cyclone. Although there was the availability of other longitudinal individual-level data, our analysis only focused on individual incomes. Our study provides an in-depth insight into the microlevel impact of extratropical cyclones on individual income in New Zealand.

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APPENDIX

Table 1: Category of Tropical Cyclone

Category	Known as	10-minute Mean Wind Speed	Maximum 3-second Gust Speed
1	Tropical Cyclone	34-47 knots (63-87 km/h)	Less than 125 km/h
2	Tropical Cyclone	48-63 knots (89-117 km/h)	125-164 km/h (Destructive winds)
3	Severe Tropical Cyclone	64-85 knots (119-157 km/h)	165-224 km/h (Very destructive winds)
4	Severe Tropical Cyclone	86-107 knots (159-198 km/h)	225-279 km/h (Very destructive winds)
5	Severe Tropical Cyclone	Over 107 knots (Over 200 km/h)	Over 280 km/h (Very destructive winds)

Source: Adapted from MetService (2021).

Table 2: Description of Major Four Extratropical Cyclones in New Zealand

Title	Description
Extratropical Cyclone Gita	Cyclone Gita was initially formed from a monsoon trough in the south pacific in early February 2018. After that, it moved towards the south by crossing the tropics and made landfall in New Zealand after transitioning into an extratropical cyclone between February 20-22. It brought heavy rainfall and strong winds up to 140 km/h to some places (Daly, 2018). Extratropical cyclone Gita brought damages to the Tasman region and West Coast, Wellington, Taranaki, and Canterbury. The total amount of private insurance claims reached NZD 35.6 million (Insurance Council of New Zealand, 2021; NIWA, 2018b).
Extratropical Cyclone Fehi	Cyclone Fehi originated in the Australian Region in late January 2018 and approached the South Pacific basin on the 28th as a subtropical cyclone. After that, it continued to move south and southwest and transitioned into an extratropical cyclone when it reached New Zealand on the 1st of February. It came with a strong wind and heavy rainfall, causing floods to several regions of the country. Mostly affected regions were the West Coast, Tasman, Nelson, Wellington, and Otago. The damage and cost of the cyclone in terms of private insurance claims reached NZD 45.9 million (Insurance Council of New Zealand, 2021; NIWA, 2018a).
Extratropical Cyclone Cook	Cyclone Cook was formed from a tropical disturbance in the early April of 2017. The system turned into a category one cyclone on April 8 and hit New Caledonia. It moved to the south-southwest, transitioned into the extratropical cyclone, and reached New Zealand on April 13. Extratropical cyclone Cook hit Bay of Plenty, Northland, Auckland, Hawke's Bay, Gisborne, and Waikato regions with heavy rain and strong winds. The total amount of private insurance claims was NZD 17.2 million (Insurance Council of New Zealand, 2021; NIWA, 2017b).
Extratropical Cyclone Debbie	Cyclone Debbie was recognized as a low-pressure system that originated in the Coral Sea in the 3rd week of March 2017. It gained strength and turned into a category three tropical cyclone when it first made its landfall in Queensland, Australia, on the 28th of March. A week later, cyclone Debbie's remnants crossed New Zealand (3rd-6th April) after losing its tropical characteristics. It caused severe floods in several parts of the country. A town named Edgecumbe of the Bay of Plenty region was evacuated to avoid risk from flooding (Ward, 2017). Besides, part of Auckland, Manawatu-Wanganui, Hawke's Bay, and Canterbury were severely affected by the cyclone. The total amount of private insurance claims reached NZD 91.46 million (Insurance Council of New Zealand, 2021; NIWA, 2017a).

Table 3: List of Extratropical Cyclones in New Zealand (NZ) 2018-1996

Date	Title	Cyclone Affected Regions, New Zealand
20-2-2018	Extratropical Cyclone Gita	Tki:2w, Wgn:3w, Tas:3r3w, Wst:3w, Cny: 1r
01-2-2018	Extratropical Cyclone Fehi	Ald:3r, Wgn: 3r 3w, Tas: 3r 3w, Wst: 3r 1w, Ota: 2r
11-04-2017	Extratropical Cyclone Cook	Nld:2r, Wko:3r, Bop:2w, Gsb:3r, Hby:3r3w, Mrb:3r
3-4-2017	Extratropical Debbie	Nld:3r, Ald:2r, Wko:3r, Bop:1r, Hby:3r, Hor:2r, Wgn:2r, Cny: 3r3w
15-3-2015	Extratropical Cyclone Pam	Gsb:3r
14-3-2014	Extratropical Cyclone Lusi	Nld:3w, Ald:3w, Wko:3r
19-2-2009	Extratropical Cyclone Innis	Ald:3r, Wko:3r, Bop:3r3w, Tki:3r, Wgn:3r, Wst:3r, Cny: 3r, Ota:3r
20-1-2008	Extratropical Cyclone Funa	Hby:3w, Tki:3w, Hor:2w, Wgn:3w
27-2-2004	Extratropical Cyclone Ivy	Nld:3r, Ald:3r 3w, Wko:3r, Bop:3r, Hby:3r, Tki:3r, Hor:2r, Wgn:3r
12-4-2001	Extratropical Cyclone Sose	Nld:1r 3w, Ald:3r, Wko: 3r, Bop:3r, Hor: 3w, Mrb:3w
28-3-1998	Extratropical Cyclone Yali	Wgn:3w3r, Tas:3r, Mrb:3w, Wst:2w3r, Sld:3w3r
11-3-1997	Extratropical Cyclone Gavin	Nld:3r3w, Wko:3w3r, Bop:3w3r, Gsb:3w3r
10-1-1997	Extratropical Cyclone Drena	Nld:3w, Ald:2w, Wko:3w3r, Tki:3w, Tas:3w, Cny: 3w3r, Ota:3r, Sld:2r
28-12-1996	Extratropical Cyclone Fergus	Nld:2r, Ald:2r, Wko:1r3w, Bop:3w, Gsb:3w
31-3-1996	Extratropical Cyclone Beti	Gsb:3r, Hby:3r3w

Source: NIWA and MetService Historical Weather Events (HWE) Catalogue

Indicators: Nld: Northland, Ald: Auckland, Wko: Waikato, Bop: Bay of Plenty, Gsb: Gisborne, Hby: Hawke's Bay, Tki: Taranaki, Wgn: Wellington, Tas: Tasman, Mrb: Marlbrough, Wst: West Coast, Cny: Canterbury, Ota: Otago, Sld: Southland, Chi: Christchurch, Hor: Horowhenua.
High likelihood = 1, Moderate likelihood = 2, Low likelihood = 3, r - Rain, w – Wind.

Table 4: Types of Individual Income

Income Type	Description
WAS	The total amount of income received by the individuals for the specified tax year from Wages and Salaries.
WHP	The total amount of income received by the individuals for the specified tax year from withholdings payments.
BEN	The total amount of income received by the individuals for the specified tax year from benefits payments.
ACC	The total amount of income received by the individuals for the specified tax year from ACC payments.
PEN	The total amount of income received by the individuals for the specified tax year from Pension payments.
PPL	The total amount of income received by the individuals for the specified tax year Paid parental leave payments.
STU	The total amount of income received by the individuals for the specified tax year from Student Allowance payments.
C00	The total amount of income received by the individuals for the specified tax year from director/shareholders receiving company income.
C01	The total amount of income received by the individuals for the specified tax year from company director/shareholders paying themselves a wage and salary.
C02	The total amount of income received by the individuals for the specified tax year from company director/shareholders paying themselves withholding payments.
P00	The total amount of income received by the individuals for the specified tax year from partners receiving partnership income.
P01	The total amount of income received by the individuals for the specified tax year from partners paying themselves a wage and salary.
P02	The total amount of income received by the individuals for the specified tax year from partners paying themselves withholding payments.
S00	The total amount of income received by the individuals for the specified tax year from sole traders receiving net profits.
S01	The total amount of income received by the individuals for the specified tax year from sole traders paying themselves a wage and salary.
S02	The total amount of income received by the individuals for the specified tax year from sole traders paying themselves withholding payments.
S03	The total amount of income received by the individuals for the specified tax year from sole traders receiving rental income.

Source: Adapted from Statistics New Zealand's Integrated Data Infrastructure (IDI), (2021)

Table 6: Impact of Extratropical Cyclone on Individual Income (Standardized Coefficients)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	0.00600	0.00150	0.00144	0.00652
	(0.00465	(0.00745)	(0.00617)	(0.00479)
D_{2015}	0.000954	-0.00528	0.00506	0.00242
	(0.00538)	(0.00753)	(0.00608)	(0.00530)
D_{2016}	-0.00512	-0.00436	0.0105	-0.000935
	(0.00585)	(0.00819)	(0.00797)	(0.00602)
$D_{2017}^{\dagger}$	-0.0136**	-0.000392	0.0130	-0.00751
	(0.00604)	(0.00791)	(0.00869)	(0.00639)
D_{2018}	-0.00856	0.00398	0.00619	-0.00506
	(0.00615)	(0.00801)	(0.00734)	(0.00624)
D_{2019}	-0.0121	-0.00752	0.0229**	-0.00270
	(0.00744)	(0.00870)	(0.0103)	(0.00772)
R^2 (within)	0.037	0.0002	0.0018	0.039
R^2 (between)	0.0178	0.0011	0.0011	0.0231
Number of individuals	2,379,936	2,379,936	2,379,936	2,379,936
Number of observations	19,332,492	19,332,492	19,332,492	19,332,492

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed as standardized coefficients; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 7: Impact of Extratropical Cyclone on Above-median Individual Income (Standardized Coefficients)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	0.0049	-0.0119	-0.00136	0.00268
	(0.00683)	(0.00894)	(0.013)	(0.00752)
D_{2015}	0.00201	-0.0157	-0.000449	-0.000153
	(0.00772)	(0.0116)	(0.0114)	(0.00758)
D_{2016}	-0.00443	-0.0106	0.0148	0.000797
	(0.00822)	(0.01)	(0.0131)	(0.00807)
$D_{2017}^{\dagger}$	-0.0127	-0.0112	0.0234*	-0.00352
	(0.00815)	(0.0103)	(0.014)	(0.00833)
D_{2018}	-0.00869	0.00704	0.01	-0.00320
	(0.00816)	(0.0114)	(0.0123)	(0.00804)
D_{2019}	-0.0135	-0.0193	0.0414**	0.00238
	(0.0104)	(0.0131)	(0.0167)	(0.0101)
R^2 (within)	0.094	0.0004	0.0037	0.105
R^2 (between)	0.0123	0.000	0.0007	0.0150
Number of individuals	1,562,673	1,562,673	1,562,673	1,562,673
Number of observations	9,530,400	9,530,400	9,530,400	9,530,400

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed as standardized coefficients; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income (above-median) from the tax year 2010-2019 The median income is calculated from total individual income from the extratropical cyclone-affected meshblocks in 2016. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 8: Impact of Extratropical Cyclone on Below-median Individual Income (Standardized Coefficients)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	0.0011	0.00152	-0.000282	0.00111
	(0.00192)	(0.00874)	(0.00281)	(0.00214)
D_{2015}	-0.00221	-0.00258	-0.00122	-0.00293
	(0.00201)	(0.0101)	(0.00286)	(0.00228)
D_{2016}	0.000845	0.000528	0.000331	0.00101
	(0.00203)	(0.0108)	(0.00289)	(0.00233)
$D_{2017}^{\dagger}$	0.00151	0.00423	0.00324	0.00332
	(0.00204)	(0.0104)	(0.0027)	(0.00231)
D_{2018}	0.00127	-0.000094	0.00197	0.00204
	(0.00197)	(0.0101)	(0.00262)	(0.00226)
D_{2019}	0.000906	-0.00891	0.00372	0.00138
	(0.00209)	(0.0117)	(0.00348)	(0.00258)
R^2 (within)	0.0005	0.0006	0.0005	0.0012
R^2 (between)	0.0155	0.0023	0.0000	0.0246
Number of individuals	1,865,736	1,865,736	1,865,736	1,865,736
Number of observations	9,802,092	9,802,092	9,802,092	9,802,092

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed as standardized coefficients; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income (below-median) from the tax year 2010-2019. The median income is calculated from total individual income from the extratropical cyclone-affected meshblocks in 2016. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 9: Impact of Extratropical Cyclone on Individual Income (Male Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	259.7	92.08	158.8	510.6
	(303.2)	(60.23)	(217.1)	(349.4)
D_{2015}	-102.8	55.97	416.2**	369.4
	(345.1)	(55.69)	(203.2)	(369.0)
D_{2016}	-491.3	-0.812	517.5**	25.41
	(387.7)	(58.05)	(254.5)	(428.1)
$D_{2017}^{\dagger}$	-876.2**	79.85	613.5**	-182.9
	(393.6)	(59.41)	(281.5)	(446.1)
D_{2018}	-780.8**	59.86	342.3	-378.6
	(392.7)	(60.95)	(234.8)	(430.4)
D_{2019}	-1,022**	-63.19	968.1***	-117.4
	(483.7)	(57.72)	(331.6)	(542.5)
R^2 (within)	0.038	0.0003	0.0017	0.039
R^2 (between)	0.0193	0.0077	0.0017	0.0248
Number of individuals	1,167,486	1,167,486	1,167,486	1,167,486
Number of observations	9,536,529	9,536,529	9,536,529	9,536,529

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 10: Impact of Extratropical Cyclone on Individual Income (Female Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	211.0	-68.52	-31.99	110.5
	(226.4)	(47.62)	(92.18)	(224.1)
D_{2015}	189.2	-98.98*	-142.1	-51.85
	(267.1)	(53.32)	(105.5)	(264.0)
D_{2016}	116.8	-56.87	-127.5	-67.52
	(278.5)	(60.32)	(139.8)	(286.1)
$D_{2017}^{\dagger}$	-201.9	-91.91*	-148.1	-442.0
	(296.4)	(55.61)	(145.3)	(314.6)
D_{2018}	139.6	-37.38	-110.4	-8.196
	(313.7)	(53.89)	(129.2)	(317.3)
D_{2019}	59.16	-25.64	-150.2	-116.7
	(363.6)	(67.15)	(174.1)	(372.6)
R^2 (within)	0.039	0.0007	0.0024	0.043
R^2 (between)	0.0201	0.0093	0.0007	0.0268
Number of individuals	1,212,450	1,212,450	1,212,450	1,212,450
Number of observations	9,795,960	9,795,960	9,795,960	9,795,960

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 11: Impact of Extratropical Cyclone on Individual Income (European Ethnic Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	305.8	23.99	86.78	416.6*
	(223.2)	(44.27)	(148.8)	(250.1)
D_{2015}	261.2	-25.93	154.5	389.8
	(253.2)	(43.14)	(144.3)	(267.0)
D_{2016}	156.3	-62.00	159.5	253.8
	(282.6)	(47.27)	(182.2)	(309.0)
$D_{2017}^{\dagger}$	-513.0*	-40.53	259.8	-293.8
	(294.0)	(46.28)	(199.9)	(331.3)
D_{2018}	-356.8	19.71	142.3	-194.8
	(303.8)	(46.44)	(167.0)	(326.3)
D_{2019}	-454.5	-35.58	482.2**	-7.880
	(367.8)	(51.44)	(237.8)	(404.7)
R^2 (within)	0.028	0.0002	0.002	0.030
R^2 (between)	0.0160	0.0000	0.0008	0.0194
Number of individuals	1,706,877	1,706,877	1,706,877	1,706,877
Number of observations	14,434,296	14,434,296	14,434,296	14,434,296

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 12: Impact of Extratropical Cyclone on Individual Income (Maori Ethnic Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	-76.68	-167.7	131.6	-112.8
	(538.3)	(173.3)	(141.5)	(496.6)
D_{2015}	-740.6	-237.1	219.9	-757.8
	(768.2)	(197.7)	(153.3)	(722.6)
D_{2016}	-1,635**	189.9	-60.33	-1,506**
	(766.3)	(221.0)	(192.9)	(738.5)
$D_{2017}^{\dagger}$	-1,359*	125.7	-240.2	-1,474**
	(765.8)	(206.0)	(155.3)	(734.9)
D_{2018}	-1,114	-61.24	42.94	-1,132
	(763.0)	(205.5)	(194.5)	(716.9)
D_{2019}	-1,047	-64.54	288.6	-823.3
	(823.7)	(217.0)	(339.6)	(809.5)
R^2 (within)	0.049	0.001	0.0016	0.059
R^2 (between)	0.0392	0.0159	0.0013	0.0665
Number of individuals	180,894	180,894	180,894	180,894
Number of observations	1,507,440	1,507,440	1,507,440	1,507,440

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 13: Impact of Extratropical Cyclone on Individual Income (Pacific Ethnic Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	-73.08	236.0	-92.99	69.98
	(643.9)	(157.0)	(220.5)	(600.0)
D_{2015}	-1,370*	505.2***	-142.8	-1,007
	(798.5)	(193.2)	(213.7)	(756.5)
D_{2016}	-1,004	212.3	-152.4	-944.6
	(843.8)	(189.8)	(198.0)	(789.7)
$D_{2017}^{\dagger}$	-858.5	326.2*	-105.4	-637.7
	(888.5)	(197.1)	(236.3)	(840.3)
D_{2018}	-298.8	141.8	-244.7	-401.8
	(867.0)	(183.8)	(386.2)	(878.0)
D_{2019}	214.6	231.2	-245.4	200.4
	(1,032)	(225.1)	(206.2)	(984.8)
R^2 (within)	0.099	0.002	0.001	0.094
R^2 (between)	0.0515	0.0242	0.0008	0.0778
Number of individuals	116,880	116,880	116,880	116,880
Number of observations	894,624	894,624	894,624	894,624

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 14: Impact of Extratropical Cyclone on Individual Income (Asian Ethnic Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	47.98	-104.4	56.93	0.546
	(559.8)	(81.82)	(213.3)	(563.9)
D_{2015}	-121.0	-57.99	71.15	-107.8
	(633.9)	(91.00)	(251.2)	(651.3)
D_{2016}	-811.5	-29.42	470.3	-370.6
	(648.5)	(91.64)	(315.3)	(678.9)
$D_{2017}^{\dagger}$	109.8	30.50	352.8	493.1
	(642.1)	(82.53)	(368.8)	(689.9)
D_{2018}	283.1	1.654	103.4	388.2
	(650.4)	(94.71)	(339.2)	(691.1)
D_{2019}	-435.0	-134.5	144.1	-425.4
	(797.5)	(87.35)	(369.4)	(823.5)
R^2 (within)	0.116	0.0011	0.004	0.112
R^2 (between)	0.0183	0.0174	0.0020	0.0245
Number of individuals	321,051	321,051	321,051	321,051
Number of observations	2,102,832	2,102,832	2,102,832	2,102,832

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 15: Impact of Extratropical Cyclone on Individual Income (MELAA Ethnic)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	-1,549	66.74	-484.8	-1,967
	(2,226)	(446.7)	(1,115)	(2,422)
D_{2015}	-2,734	-234.0	217.2	-2,751
	(2,749)	(352.2)	(613.5)	(2,813)
D_{2016}	-3,612	-313.5	2,708	-1,218
	(2,455)	(381.7)	(2,463)	(3,421)
$D_{2017}^{\dagger}$	-2,828	-560.2	-260.0	-3,648
	(2,149)	(518.2)	(830.8)	(2,343)
D_{2018}	3,724**	-356.6	-370.3	2,997*
	(1,896)	(382.9)	(684.6)	(1,806)
D_{2019}	679.7	-387.4	-460.4	-168.0
	(2,019)	(384.5)	(1,232)	(2,205)
R^2 (within)	0.095	0.001	0.006	0.112
R^2 (between)	0.0122	0.0013	0.0023	0.0209
Number of individuals	29,340	29,340	29,340	29,340
Number of observations	184,773	184,773	184,773	184,773

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 16: Impact of Extratropical Cyclone on Individual Income (Non-tertiary Education Certificate Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	-214.7	42.22	111.0	-61.52
	(308.4)	(91.92)	(145.7)	(313.8)
D_{2015}	-137.8	18.66	293.4	174.3
	(344.9)	(115.0)	(225.3)	(367.7)
D_{2016}	-427.5	-194.6*	15.77	-606.4
	(380.8)	(113.0)	(287.0)	(439.5)
$D_{2017}^{\dagger}$	-547.7	9.840	-200.1	-738.0*
	(399.8)	(117.3)	(261.2)	(439.5)
D_{2018}	-263.0	69.99	-148.6	-341.6
	(394.3)	(128.5)	(203.5)	(410.4)
D_{2019}	179.0	-50.45	371.9	500.4
	(432.6)	(122.8)	(313.6)	(497.0)
R^2 (within)	0.003	0.0011	0.0004	0.003
R^2 (between)	0.0112	0.0024	0.0004	0.0161
Number of individuals	381,882	381,882	381,882	381,882
Number of observations	3,376,431	3,376,431	3,376,431	3,376,431

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 17: Impact of Extratropical Cyclone on Individual Income (Tertiary Education Certificate Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	-7.678	57.24	-19.68	29.88
	(328.6)	(66.29)	(159.3)	(336.5)
D_{2015}	27.07	-53.36	253.5	227.2
	(366.4)	(63.27)	(189.8)	(377.0)
D_{2016}	-637.1	-37.11	273.5	-400.7
	(396.2)	(81.61)	(201.5)	(406.8)
$D_{2017}^{\dagger}$	-440.6	-20.75	236.5	-224.8
	(417.2)	(72.11)	(237.2)	(441.1)
D_{2018}	-122.6	10.47	173.9	61.70
	(429.5)	(71.30)	(169.3)	(430.1)
D_{2019}	-707.3	97.01	-230.9	-841.2
	(493.0)	(94.33)	(268.1)	(534.0)
R^2 (within)	0.039	0.0002	0.002	0.040
R^2 (between)	0.0447	0.0068	0.0021	0.0544
Number of individuals	665,988	665,988	665,988	665,988
Number of observations	5,098,605	5,098,605	5,098,605	5,098,605

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 18: Impact of Extratropical Cyclone on Individual Income (Diploma Degree Qualification Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	1,183	-294.9	-317.8	570.1
	(925.9)	(216.8)	(296.9)	(923.6)
D_{2015}	474.3	-281.9	-497.8	-305.4
	(932.1)	(257.6)	(336.3)	(949.9)
D_{2016}	929.6	-170.5	-809.2**	-50.11
	(1,035)	(282.9)	(346.5)	(1,015)
$D_{2017}^{\dagger}$	-93.61	45.63	-302.9	-350.9
	(990.4)	(267.2)	(627.4)	(1,117)
D_{2018}	-415.6	-94.45	-916.0*	-1,426
	(1,098)	(290.3)	(487.0)	(1,117)
D_{2019}	479.7	-548.1**	-753.2	-821.6
	(1,204)	(236.3)	(492.9)	(1,232)
R^2 (within)	0.046	0.001	0.002	0.054
R^2 (between)	0.0088	0.008	0.0007	0.0161
Number of individuals	75,750	75,750	75,750	75,750
Number of observations	655,707	655,707	655,707	655,707

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 19: Impact of Extratropical Cyclone on Individual Income (Bachelor Degree Qualification Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	1,183	-294.9	-317.8	570.1
	(925.9)	(216.8)	(296.9)	(923.6)
D_{2015}	474.3	-281.9	-497.8	-305.4
	(932.1)	(257.6)	(336.3)	(949.9)
D_{2016}	929.6	-170.5	-809.2**	-50.11
	(1,035)	(282.9)	(346.5)	(1,015)
$D_{2017}^{\dagger}$	-93.61	45.63	-302.9	-350.9
	(990.4)	(267.2)	(627.4)	(1,117)
D_{2018}	-415.6	-94.45	-916.0*	-1,426
	(1,098)	(290.3)	(487.0)	(1,117)
D_{2019}	479.7	-548.1**	-753.2	-821.6
	(1,204)	(236.3)	(492.9)	(1,232)
R^2 (within)	0.046	0.001	0.002	0.054
R^2 (between)	0.0088	0.008	0.0007	0.0161
Number of individuals	75,750	75,750	75,750	75,750
Number of observations	655,707	655,707	655,707	655,707

Note: † = Extratropical cyclone-affected meshblocks in 2017.
Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table 20: Impact of Extratropical Cyclone on Individual Income (Post-bachelor Degree Educational Qualification Group)

	Wage & Salary (1)	Benefit & Compensation (2)	Self-employment (3)	Wage, Benefit & Self-employment (4)
D_{2014}	23.74	47.63	103.7	175.0
	(412.9)	(118.7)	(289.2)	(464.6)
D_{2015}	-193.8	-29.95	387.0	163.3
	(469.0)	(93.45)	(290.6)	(495.0)
D_{2016}	-142.9	69.92	791.8	718.8
	(517.9)	(104.1)	(482.2)	(651.1)
$D_{2017}^{\dagger}$	-47.44	-33.13	930.0*	849.4
	(539.7)	(105.7)	(558.3)	(723.0)
D_{2018}	-391.3	-20.45	482.1	70.42
	(560.5)	(102.0)	(477.0)	(703.9)
D_{2019}	-134.0	-163.3*	951.5	654.2
	(670.2)	(95.50)	(635.0)	(860.3)
R^2 (within)	0.033	0.0001	0.003	0.039
R^2 (between)	0.0061	0.0014	0.0005	0.0086
Number of individuals	425,151	425,151	425,151	425,151
Number of observations	3,769,743	3,769,743	3,769,743	3,769,743

Note: † = Extratropical cyclone-affected meshblocks in 2017.

Regression coefficients are expressed in New Zealand Dollars; all regressions include year and individual fixed effects. The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. Clustered standard errors (at the individual level) are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Figure 1: Extratropical Cyclone Affected Regional Council in New Zealand

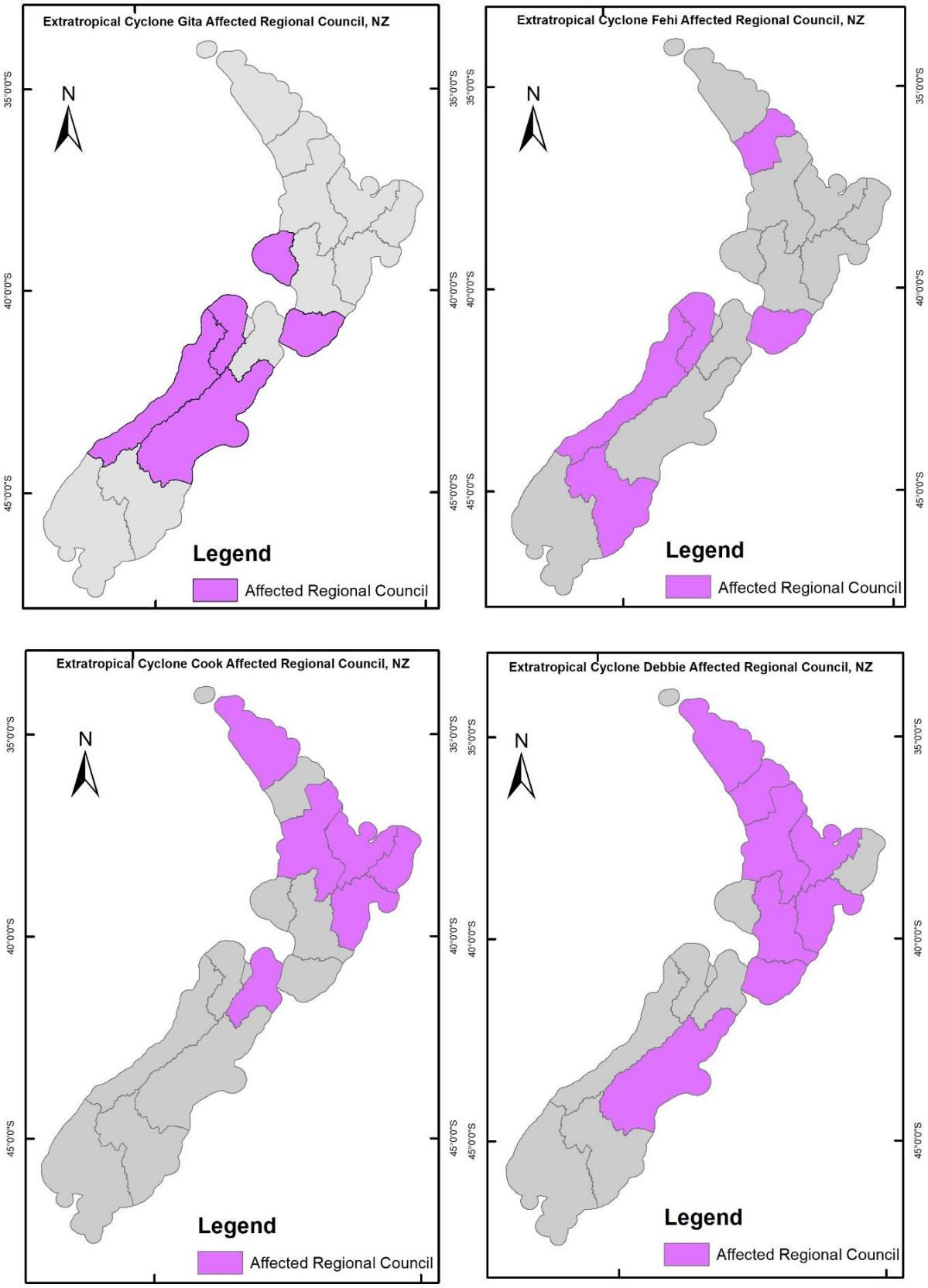


Figure 2: Extratropical Cyclone Affected Meshblock (At Least Two Weather-related Insurance Claims) in New Zealand

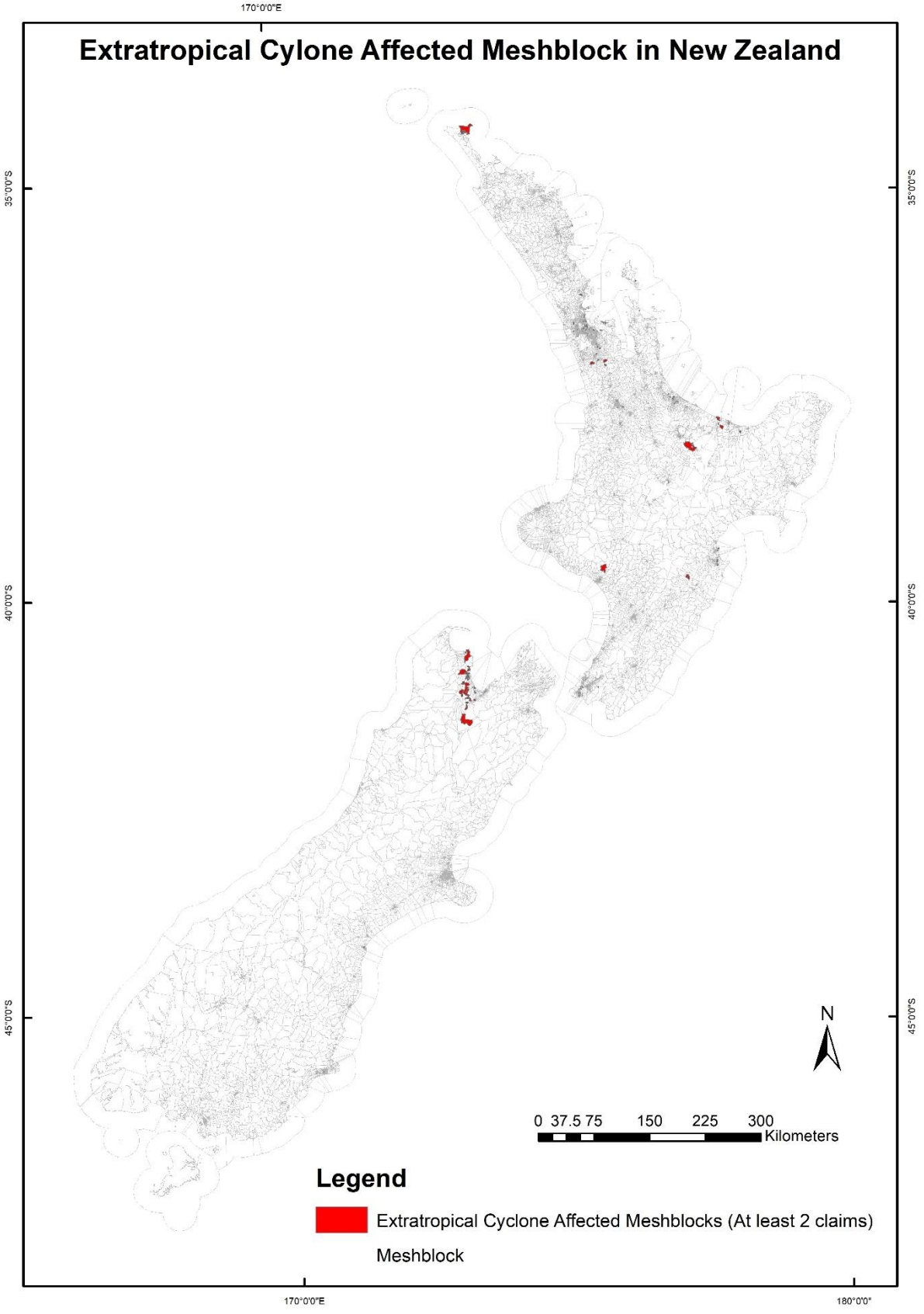
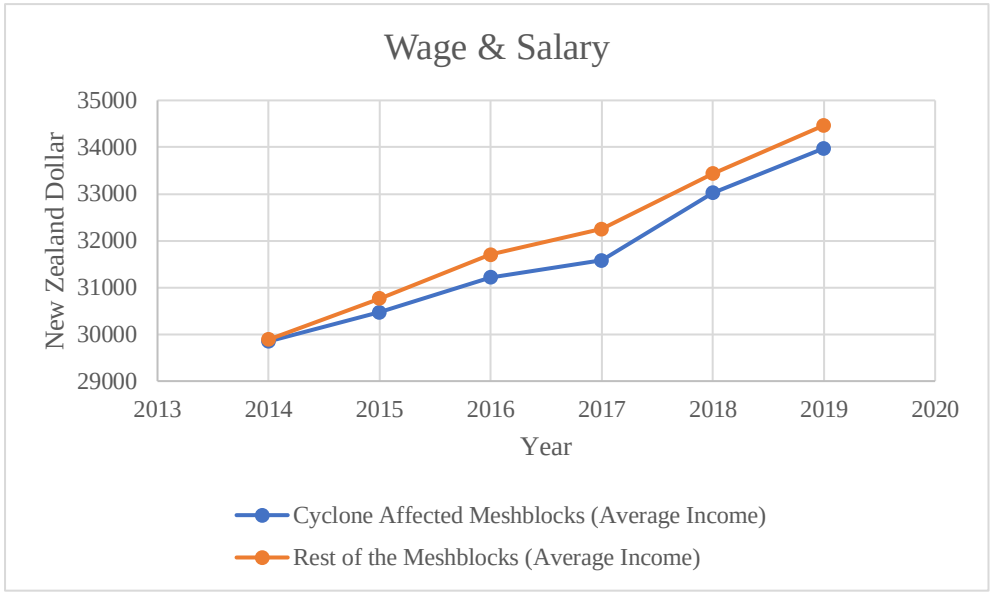
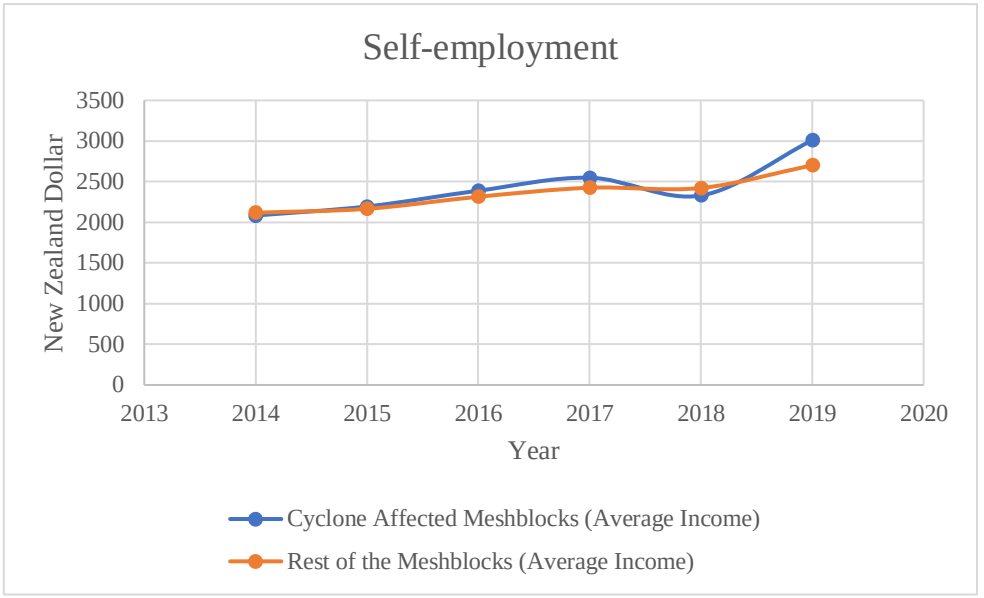
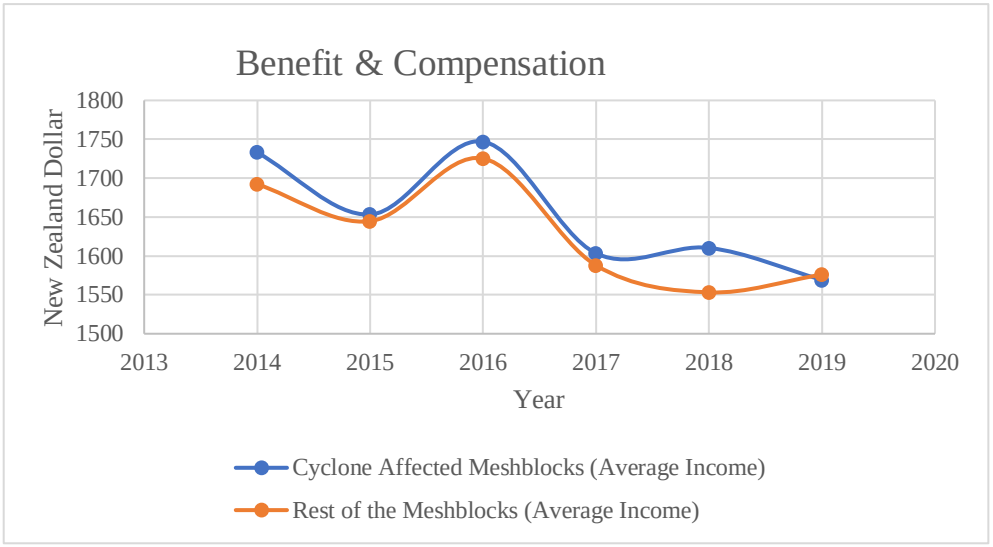


Figure 3: Average Individual Income Distribution in New Zealand







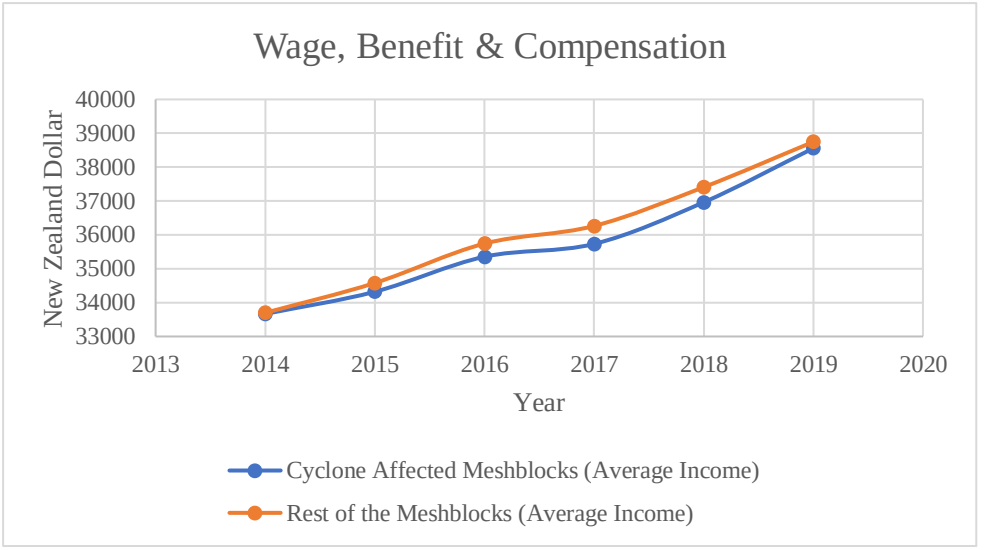
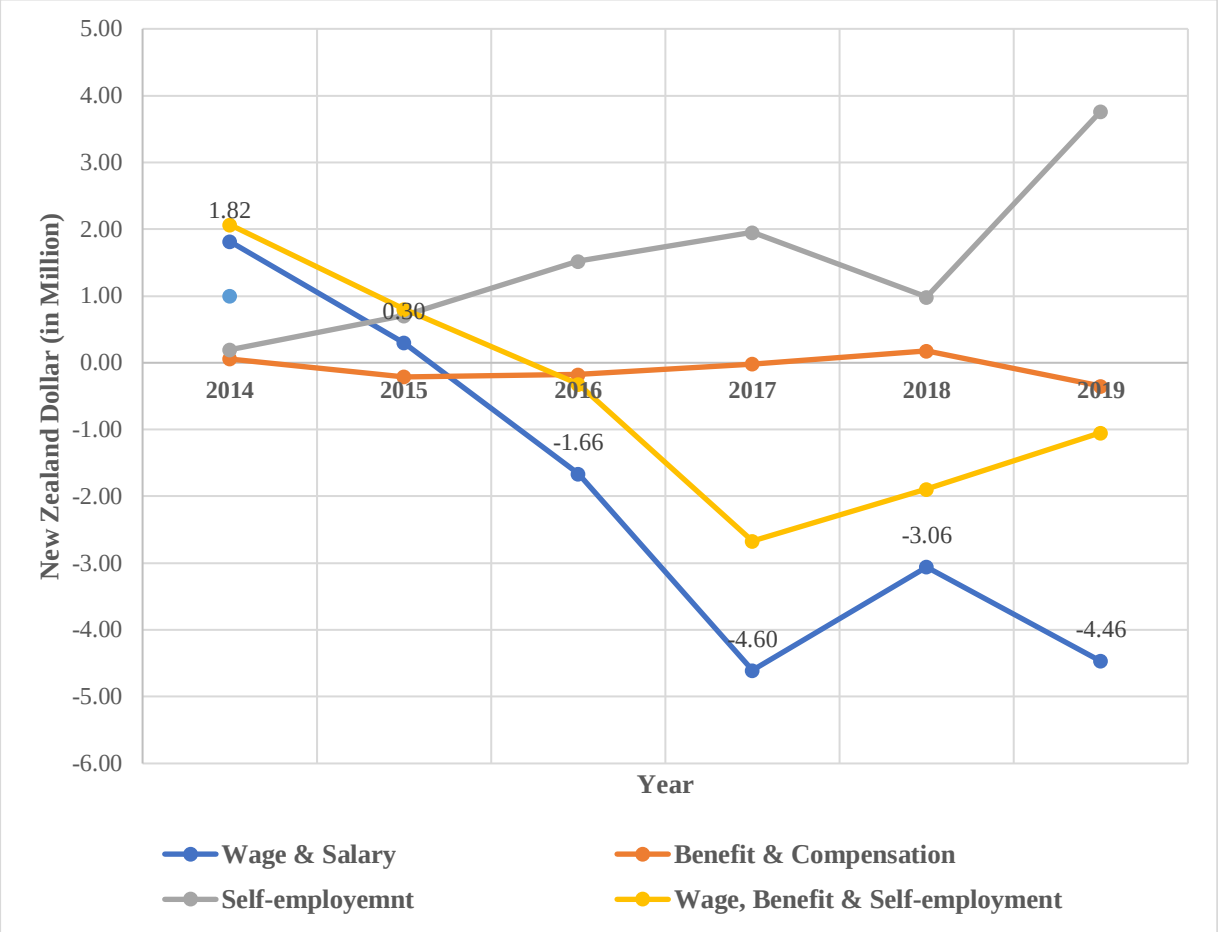
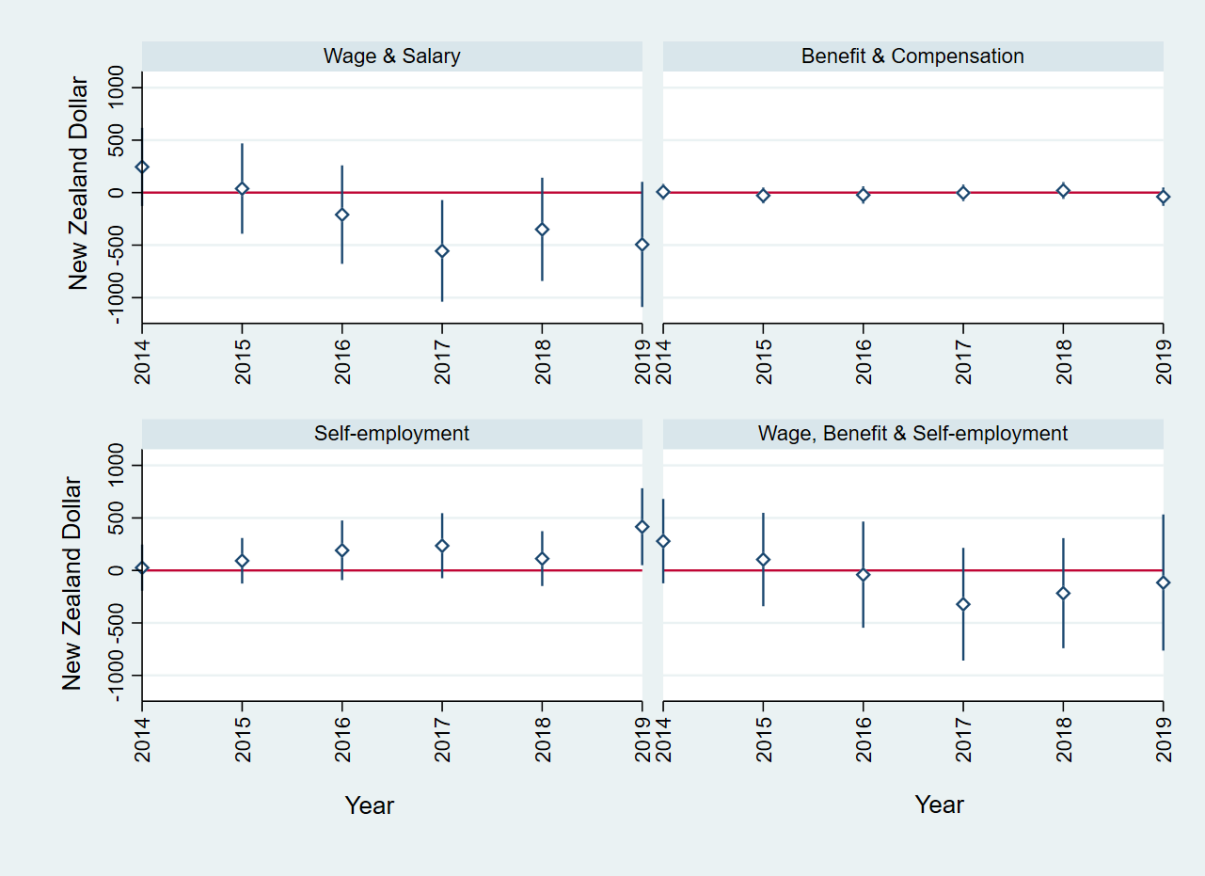


Figure 4: Aggregate Economic Cost of Extratropical Cyclone on Affected Meshblocks in New Zealand



Notes: The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. These figures are the product of regression coefficients and the number of individuals in affected meshblocks in the corresponding year. Every regression is adjusted for individual and year fixed effects. Robust standard errors adjusted for clustering at the individual level.

Figure 5: Impact of Extratropical Cyclone and Individual Incomes (Absolute Coefficient)



Notes: The analysis is conducted based on a panel of individual income from the tax year 2010-2019. The cyclone-affected meshblocks are based on at least two weather-related insurance claims. These figures indicate the point estimates of the impact of extratropical cyclones (occurred in 2017) on individual incomes by using the specification in equation (1). Regression coefficients are expressed as New Zealand Dollar. Every regression is adjusted for individual and year fixed effects. Robust standard errors adjusted for clustering at the individual level. 95 percent confidence intervals are shown for each point estimate.

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