Effects of Weather Events on Hospitalization Rates and Medical Expenditure in New Zealand

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Abstract

Climate change consequences include rising temperatures, heavy rain, and storms threaten human health. This study intends to investigate the impact of weather-related events on hospitalization rates and medical expenses in New Zealand. This study has utilized secondary weather data obtained from the National Institute of Water and Atmospheric Research (NIWA), as well as hospital discharge rates by ethnic groups and medical expenditure data obtained from Health New Zealand. Panel data regression models (fixed effect and random effect) have been implemented to investigate the association between health variables and meteorological events. The findings indicate that while the average temperature has an effect on the rate of hospital release, rainfall is inversely correlated with hospitalization. The random effect model has reliably found that average temperature and total rainfall has significant impacts on medical expenditure. Consequently, the rising temperature is leading to an increase in both hospital admissions and medical expenses in New Zealand. While we may not have a direct role in dealing with climate change and temperature rise, this study can assist health-policy authority in raising awareness among the public about the imminent concerns that climate change poses to the health sector.

Keywords: Temperature, Rainfall, Hospital Discharge, Medical Expenditure, New Zealand

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1. Introduction

In recent years, there has been a consistent increase in temperatures. The worldwide mean near-surface temperature in 2023 exceeded the 1850-1900 average by almost 1.40°C, establishing it as the hottest year ever recorded. From 2014 to 2023, the highest temperatures have been seen, with 2023 experiencing record monthly temperatures from June to December. The shift from La Niña to El Niño in 2023 contributed to the increased temperatures, (Rahim, et al., 2024). Across the globe, there has been a noticeable increase in weather phenomena such as heatwaves, storms, and intense rains, primarily attributed to changes in climatic patterns. Along with the global scenario, New Zealand's weather patterns are changing, with extreme events occurring more frequently and with greater intensity. New Zealand is affected by a range of weather phenomena, such as tropical cyclones, heavy rainfall, floods, droughts, snowstorms, heatwaves, earthquakes, tsunamis, and the excessive occurrence of El Nino and La Nina (Cashin et al., 2017). In 2022, the average temperature was 13.15°C, above the average temperature from 1981-2010 by 0.96°C. This makes it one of the warmest recorded years, according to the National Institute of Water and Atmospheric Research (NIWA) in 2023. The distribution of rainfall exhibited significant variation among different locations. While Canterbury endured protracted periods of drought, Auckland was hit by flooding as a result of high rainfall (NIWA, 2023). The climate shifts had substantial consequences for both public health and infrastructure.

Weather-related health concerns encompass injuries and illnesses resulting from indirect effects on the quality of air and water. The impact on public health is diverse, encompassing respiratory issues and the availability of healthcare services (Hales et al., 2013). On a global scale, there has been an increase in hospital admissions as a result of meteorological conditions. The World Health Organization (WHO) reported a surge in hospital admissions due to heat-related illnesses in the years 2022 and 2023. This spike also resulted in an intensified burden on healthcare systems due to escalated expenses linked to the management of health disorders caused by meteorological conditions. Global health spending has enhanced due to the necessity of handling the epidemic, distributing vaccines, and resuming postponed medical treatments. Countries with strong healthcare systems, such as the United States, dedicated a substantial proportion of their Gross Domestic Product (GDP) to healthcare (Okamoto et al., 2024). New Zealand encounters a range of meteorological phenomena as a result of its geographical position in the South Pacific Ocean and its varied topography. As a result of severe weather events, individuals are exposed to many health risks such as waterborne diseases, starvation, respiratory problems, mental health disorders, chronic illnesses, injuries, and vector-borne diseases. Heatwaves, cyclones, storms, flooding, drought, and heavy rainfall are all examples of weather phenomena that have contributed to an upsurge in hospital admissions in New Zealand in the last ten years. The Ministry of Health stated in 2023 that heat-related hospital admissions increased in the months and lung diseases increased in the winter (Achebak et al., 2023). Consequently, the rising medical expenses and declining human capital will have a detrimental impact on the overall economy. In 2023-2024, New Zealand's health expenditure budget is to be NZD 16.68 billion, (Ministry of Health, 2024).

Cyclones have a detrimental impact on salary and wage income across various characteristics. It significantly impacts individual income from wages, salaries, benefits, and solo traders in New Zealand (Roy, et al., 2022). On ther other hand, large flood losses caused by private insurance did not significantly affect individual yearly incomes, including salary, wage, self-employment, and total income across multiple criteria in New Zealand (Roy, 2023). In the year of the extratropical cyclone, firms in agricultural, wholesale commerce, banking and insurance services, and transportation saw a large fall in annual profit compared to unaffected firms. Floods and wildfires did not significantly damage the profit of forestry enterprises in New Zealand (Roy and Noy, 2023). Additionally, the correlation between temperature and precipitation and the incidence of violent crimes and property crimes in New Zealand is statistically significant (Horrocks and Menclova, 2011). Extreme weather and climatic events including heat waves, cyclones, and floods continue to inflict human morbidity and mortality and harm mental health (Ebi, et al., 2021). Bangladesh reported 145.9 disaster-related injuries, 14.4 impairments, and 21.0 deaths per 100,000 in 2009–2014. Floods caused the most injury, disability, and death, followed by thunderstorms (Ahmed, et al., 2021). The main effect of excessive temperature was far more likely than the additional effect in mortality, as were respiratory disease and elderly hospitalizations in Vietnam (Dang, et al., 2019). Significant correlation exists between air pollution and cardio-respiratory admissions in Christchurch, New Zealand. Increased air pollution led to a 3.37% increase in respiratory admissions across all age groups. A 1.26% increase in cardiac admissions was observed for each interquartile air pollution increase (McGowan, et al., 2002). Previous research suggested that electricity prices strongly linked with hospital asthma admissions. This supports the idea that electricity prices affect asthma through home heating. Although asthma admissions are greater in summer, electricity rates affect them more in winter (Menclova, et al., 2016).

None of the preceding literature has examined the simultaneous effects of significant rainfall and temperature on hospitalization and health spending. So, the main objectives of this study are:

i. To investigate the effect of weather events on hospitalization rates in New Zealand;
ii. To explore the impact of weather variation on heath expenditure in New Zealand.

This study has relevance because climate change is leading to an increased frequency of extreme weather events such as heatwaves and heavy storms. These meteorological phenomena have significant impacts on individuals' well-being, resulting in increased hospital admissions and elevated medical expenses. The rising costs of healthcare systems are being exacerbated by health issues resulting from extreme weather conditions, particularly in regions with low resources. Gaining insight into the impact of these particular weather conditions on health facilitates the development of more effective health plans and policies. With the increasing frequency of severe weather events, healthcare systems must possess robustness and preparedness to effectively handle the situation. The purpose of this study is to provide important new information about the relationship between hospital visits and medical costs and weather. The results will help healthcare systems deal with the effects of climate change in an efficient manner.

2. Methodology

2.1 Data Source and Variable Description

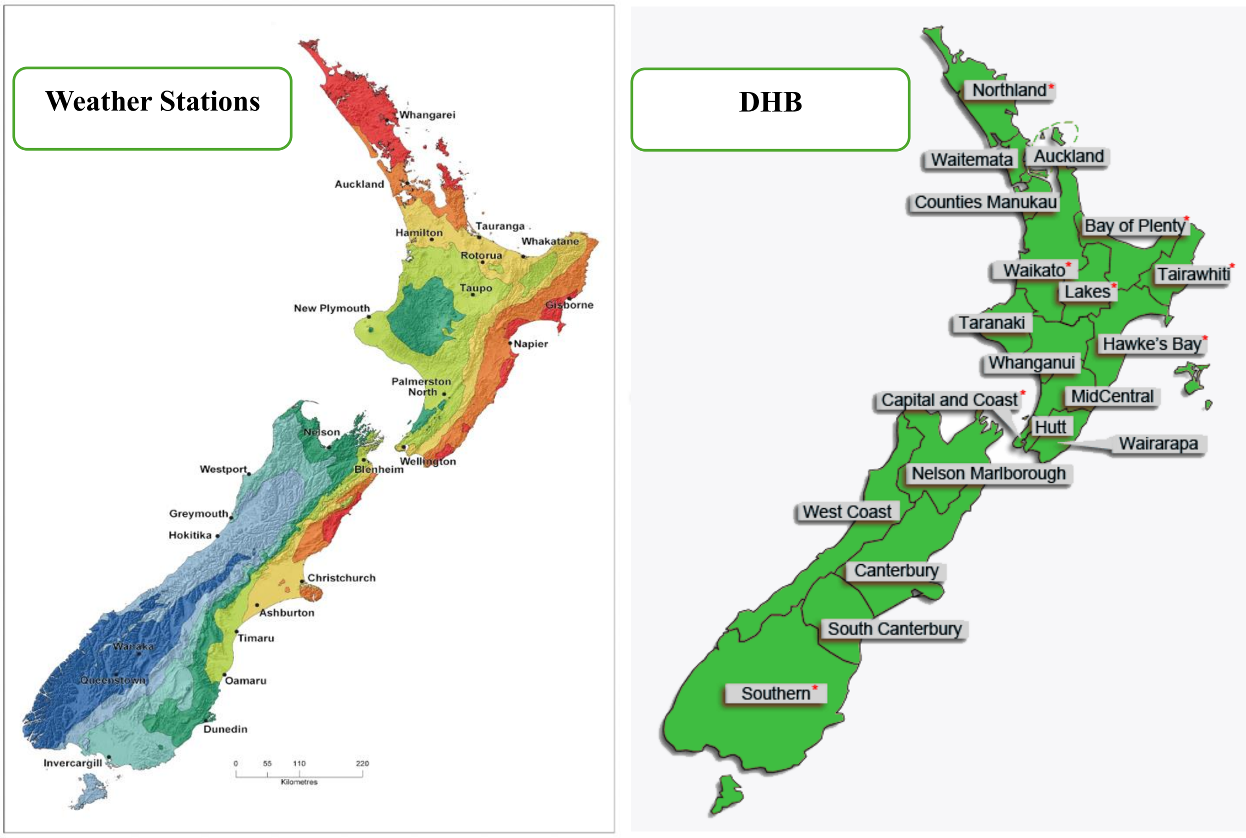
To fulfil the objectives of this study, author used secondary weather data and hospitalization as well as medical expenditure data from 2014-2019. This study is based on New Zealand, so it covered the all regions of New Zealand. Panel data is a type of data that comprises observations about various cross-sections over time. Here, panel data of different regions and years (2014-2019) have been utilized to estimate the effect of weather events on hospital discharge rate and medical expenditure of New Zealand.

Weather Data and Explanatory Variables: The weather data has been taken from the NIWA. Here, month and year-wise data of 29 regions are available in which there are sub-stations in each region. For this study, author has taken the data of weather events, i.e., mean daily temperature, mean daily maximum temperature, mean daily minimum temperature, and total rainfall from the National Climate Database of NIWA.

Hospitalization and Medical Expenditure Data and Dependent Variables: To find out the hospitalization data, author used the hospital discharge data by ethnic group. All the data of hospital discharge, she used are from the official websites of the Ministry of Health New Zealand. There are 20 District Health Board (DHB) in New Zealand. Moreover, author contacted with 'Harrison Devane' who is the Information Analyst of National Collection Data Services, Health New Zealand. He provided the medical expenditure data from their data records. Author utilized the data from 2014-2019. The author has excluded the private discharge data because it does not contain the discharge data by ethnic group. The one dependent variable for the first objective is hospital discharge which is considered by the categories of ethnic groups – Asian, Pacific, Māori and others. The medical expenditure is the dependent variable for the second objective which is measured by the New Zealand Dollar (NZD). The medical costs are GST exclusive.

<u>Data Adjustment:</u> After collecting data from two different sources, author faced the main challenge of data adjustment because DHB and NIWA weather stations have not similarly been defined. The following map (Map 1) show the weather regions considered by NIWA and DHB considered by Health NZ.

Map 1: Weather Stations of NIWA and DHBs of Health New Zealand



Sources: NIWA and Ministry of Health NZ, 2024

To adjust the data, author used the sub-stations data in STATA and found year-wise (2014-2015) mean temperature, maximum temperature, minimum temperature, rainfall values for each weather station. Then, she found which stations/regions are under which DHB from the website of Ministry of Health New Zealand. The following table (Table 1) shows the NIWA weather stations which are under 20 DHB. From the NIWA and Health NZ, the data have collected directly into excel files. Basic data cleanup has been done in order to get the data into an utilizable format. Some blank rows and columns have been discarded. In weather data, there are no stations under DHB Countries Manukau, Hutt Valley and Waitemata. These are included into Auckland and Wellington. So, author has to exclude these DHB from the dataset.

Table 1: NIWA Weather Stations under District Health Boards (DHBs)

DHB	NIWA Stations	DHB	NIWA Stations
Auckland	Central Auckland	Northland	Kaitia (North) Whangarei
Bay of Plenty	Tauranga	South Canterbury	Timaru
Canterbury	Lake Tekapo MT Cook Christchurch Kaikoura	Southern	Central Otago - Alaxandra Queenstown Lakes Dunedin Milford Sound Southland Invercargill Manapouri
Capital and Coast	Wellington	Tairāwhiti	Gisborne
Counties Manukau		Taranaki	New Plymouth
Hawke's Bay	Napier City	Waikato	Hamilton
Hutt Valley		Wairarapa	Masterton
Lakes	Rotorua Lakes Taupō	Waitematā	
MidCentral	Palmerston North	West Coast	West Port Hokitiki
Nelson Marlborough	Nelson Marlborough - Blenheim	Whanganui	Wanganui

Sources: Authors' Compilation, 2024

2.2 Quantitative Tools

To fulfil the objective (i), fixed effect model is as follows:

$$HR_{it} = B_0 + B_1 T_{it} + B_2 R_{it} + u_{it} \text{ .... (i)}$$

To fulfil the objective (ii), author has used fixed and random effect. The equation is as follows:

$$ME_{it} = B_0 + B_1 T_{it} + B_2 R_{it} + u_{it} \text{ ....(ii)}$$

The author used the Hausman test to decide whether to use a fixed effects or random effects model. Running a fixed effects model and save the estimates and running a random effects model and save the estimates and performing the Hausman test are the main process the author applied. If the Prob > chi2 (p value) value is < 0.05, she used a fixed effects model. On the other hand, she should use a random effect model if the p-value is equal or > 0.05. So, author mainly followed these steps to get the most reliable results. Here, HR is hospital discharge rate, Me is medical expenditure, T is temperature variables, R is rainfall, I is DHB and t is year.

3. Result and Discussion

3.1 Summary Statistics

This study estimates the effect of temperature and rainfall on hospital admission rate (discharge) and medical expenditure of New Zealand. So, it will consider the average, maximum and minimum daily temperature, total rainfall of different regions of New Zealand. Here, it has been seen that the maximum average temperature is 17°C, maximum temperature is 22°C and minimum temperature is -5°C in the descriptive statistics table (Table 2). Maximum total rainfall is 788mm.

Table 2: Descriptive Statistics of Weather and Health Variables

Variables	Observation	Mean	Std. Dev.	Min	Max
Average Temperature (°C)	102	15.14	1.36	12	17
Maximum Temperature (°C)	102	20.02	1.21	18	22
Minimum Temperature (°C)	102	3.69	3.96	-5	10
Total Rainfall (mm)	102	321.02	168.54	118	788
Hospital Discharge by Ethnic Group	408	12261.42	19678.4	36	99322
Medical Expenditure	102	1.87e+08	1.75e+08	1.66e+07	7.18e+08

Sources: Authors' Compilation, 2024

The table also shows that maximum hospital discharge by ethnic group is 99322 and highest maximum medical expenditure is NZD 718 million. The observations of all variables are 102 because there are 17 DHBs observations of data from 2014 to 2019. But the hospital discharge variable has 408 observations because it has been considered by the ethnic groups of Asia, Pacific, Māori and Others. The temperature and rainfall distributions of several DHBs from 2014 to 2019 are provided in Appendix, namely in (Figure 1 and Figure 2). The Appendix (Figure 3 and Figure 4) displays the trends of total hospital discharge rate and total medical expenditure of all DHBs from 2010-2023.

3.2 Panel Regression Models Estimation

3.2.1 Effects of Weather Events on Hospitalization (Discharges) in New Zealand

The effects of temperature variables and rainfall on hospital discharge rate by ethnic groups have been shown in the following table (Table 3) by the result of fixed effect panel regression model. In the first column of regression table, average temperature separately regressed the discharge rate and the result is positive and significant (5% significance level). In other words, a rise in average temperature generally leads to an increase in the rate of hospital admissions. In the second and third columns, maximum and minimum temperature separately regressed the discharge rate. The coefficient of minimum temperature is positive, meaning that an increase in minimum temperature may lead to people falling ill and being admitted to the hospital. In column four, total rainfall has negative association with discharge rate. The admission of individuals to hospitals is not influenced by an increase in the rate of rainfall. Perhaps the authority's maintenance efforts are effective in mitigating the effects of heavy rainfall. Therefore, it does not have an impact on the health of individuals, and individuals are also aware of their health. They are aware of the appropriate course of action during periods of heavy rainfall.

Table 3: Effects of Temperature and Rainfall on Hospital Discharges

Weather Events	**Discharges by Ethnic**	**Discharges by Ethnic**	**Discharges by Ethnic**	**Discharges by Ethnic**	**Discharges by Ethnic**	**Discharges by Ethnic**
Average Temperature	9.799 (0.01) *				18.402 (0.01)	18.286 (0.01) **
Maximum Temperature		-4.724 (0.00)			-34.753 (0.02)	-34.768 (0.02)
Minimum Temperature			31.985 (0.05)		35.524 (0.05)	35.491 (0.05) *
Total Rainfall				-0.033 (0.00)		-0.011 (0.00)
Constant	12420.789 (0.76)	12663.936 (0.58)	12456.394 (5.16) **	12580.554 (4.27) **	12860.241 (0.57)	12866.127 (0.56)
R^2	0.70	0.70	0.70	0.70	0.70	0.70
N	360	360	360	360	360	360

Note: * $p<0.05$; ** $p<0.01$ Sources: Authors' Compilation, 2024

All temperature variables have been regressed on the discharge rate in the fifth column. In the final column, the author included all the weather factors collectively in order to do a regression analysis on the discharge rate based on ethnic group. The analysis indicates that both the average temperature (1% significance level) and minimum temperature (5% significance level) have had a significant positive impact on the discharge rate. Nevertheless, the discharge rate is inversely correlated with both the maximum temperature and the total rainfall.

3.2.2 Effects of Weather Events on Medical Expenditure in New Zealand

The weather events are assumed to effect the medical expenditure of New Zealand. The findings of fixed effect and random effect, as well as the Hausman test, are presented in Table 4.

Table 4: Effects of Temperature and Rainfall on Medical Expenditure

Weather Events	Medical Expenditure (Fixed Effect)	Medical Expenditure (Random Effect)
Average Temperature	7061117.160 (2.06) *	7207775.899 (2.11) *
Maximum Temperature	4067012.549 (1.12)	4135402.531 (1.15)
Minimum Temperature	-1100278.830 (0.57)	-938224.649 (0.50)
Total Rainfall	4639.599 (0.19)	4418.508 (0.18) *
Constant	1000754.473 (0.02)	-3114798.709 (0.05)
N	102	102
Hausman Test (fixed or rendom)	*P* (Prob>chi2) = 0.925	

Note: * $p<0.05$; ** $p<0.01$ Sources: Authors' Compilation, 2024

Both panel regression models demonstrate that the average temperature has a significant impact on increasing medical cost in New Zealand. It is intended to indicate that individuals are becoming ailing and experiencing a variety of diseases as the average temperature begins to rise. At the end of the day, they are required to undergo medical monitoring. As a result, the authority ought to allocate additional funds to the healthcare sector. In the same way, the total rainfall has a positive association with the medical expense on health care across the nation. The rainfall coefficient has significant impact on medical expenditure in random effect model.

We know that in Hausman test, if the Prob > chi2 (*P*-value) value is < 0.05, the author uses a fixed effects model. On the other hand, we should use a random effect model if the *P*-value is equal or > 0.05. In this study, the *P*-value of Hausman test is 0.925, that is, it is greater than 0.05. So, the result of random effect model is more reliable than the fixed effect model for this study.

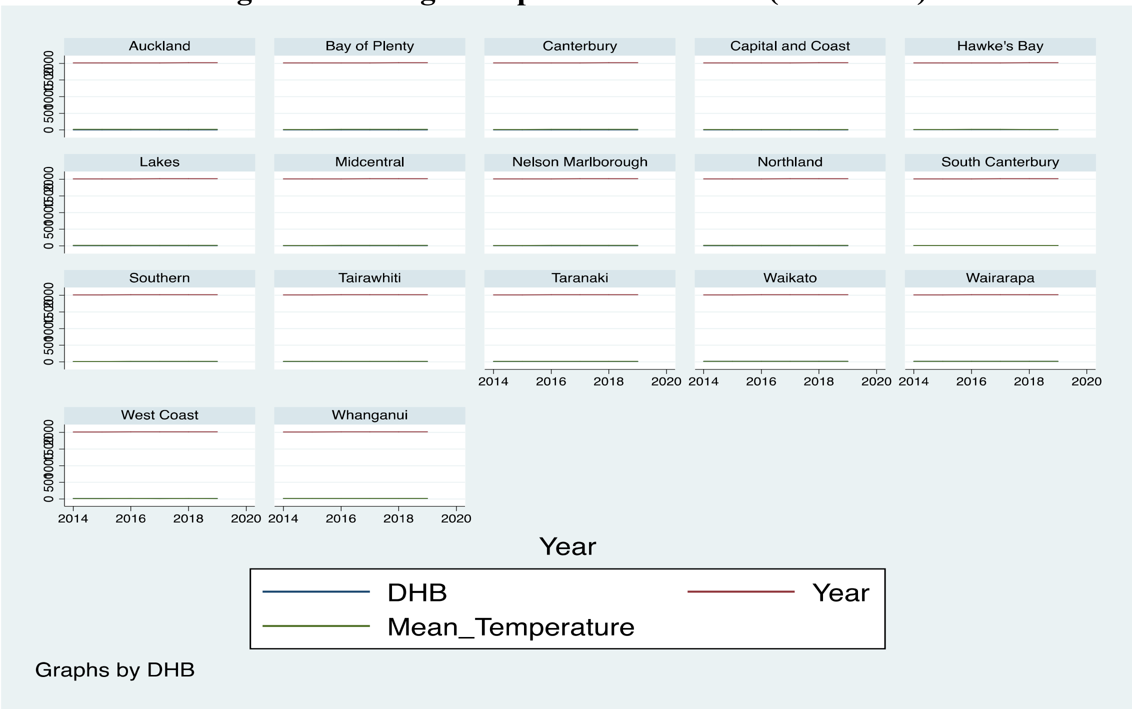
4. Conclusion

Climate change is directly exacerbating humanitarian emergencies caused by change in temperature, excessive rainfall, heatwaves, wildfires, floods, tropical storms, and hurricanes, leading to an escalation in their magnitude, occurrence, and severity. According to WHO studies, 3.6 billion people are now residing in regions that are very vulnerable to the effects of climate change. Undernourishment, malaria, diarrhea, and heat stress, respiratory problems are projected to contribute to an additional 250,000 annual fatalities between 2030 and 2050 as a result of climate change. It is projected that by 2030, the annual direct costs to health will range from $2 billion to $4 billion, excluding costs in areas that influence health, like agriculture and water and sanitation. Health difficulties may arise from extreme temperatures, especially for the elderly, babies, and outdoor labourers. Warming may bring tropical diseases like dengue fever and malaria to New Zealand. More frequent and strong extreme weather events including flooding, storm surges, forest fires, and ex-tropical cyclones may harm people's physical and mental health. Ultimately, it may result in an increase in the cost of medical care by increasing the incidence of hospital admissions.

This study has attempted to estimate the effect of temperature and rainfall on hospital admission rate and medical expenditure in New Zealand. New Zealand has a total of 20 District Health Boards (DHBs). Health New Zealand possesses statistics on hospital discharge rates and medical expenditure broken down by ethnic groupings for each DHB. In addition, NIWA has temperature and rainfall data for different stations. Author used the data (2014-2019) from these sources. Panel regression models have been applied to estimate the effect of temperature and rainfall on hospital discharge and medical cost in New Zealand. The fixed effect model indicates that both the average and minimum temperature exert significant effects on the rate of hospital admissions. However, precipitation has negative association with the release of patients from the hospital. The random effect model is significantly more suitable for estimating the impact of meteorological variables on medical expenditure, determined by the Hausman test. The findings demonstrate that the healthcare expenditures of New Zealand are significantly influenced by both the average temperature and the total rainfall. Therefore, it is recommended that individuals become more aware of their health, as the temperature and rainfall patterns have been altered as a result of climate change. Furthermore, health policymakers should be more committed to implementing policies that will mitigate medical expenses, address the health challenges associated with the evolving temperature and rainfall patterns, and guarantee the availability of hospital facilities and medical services.

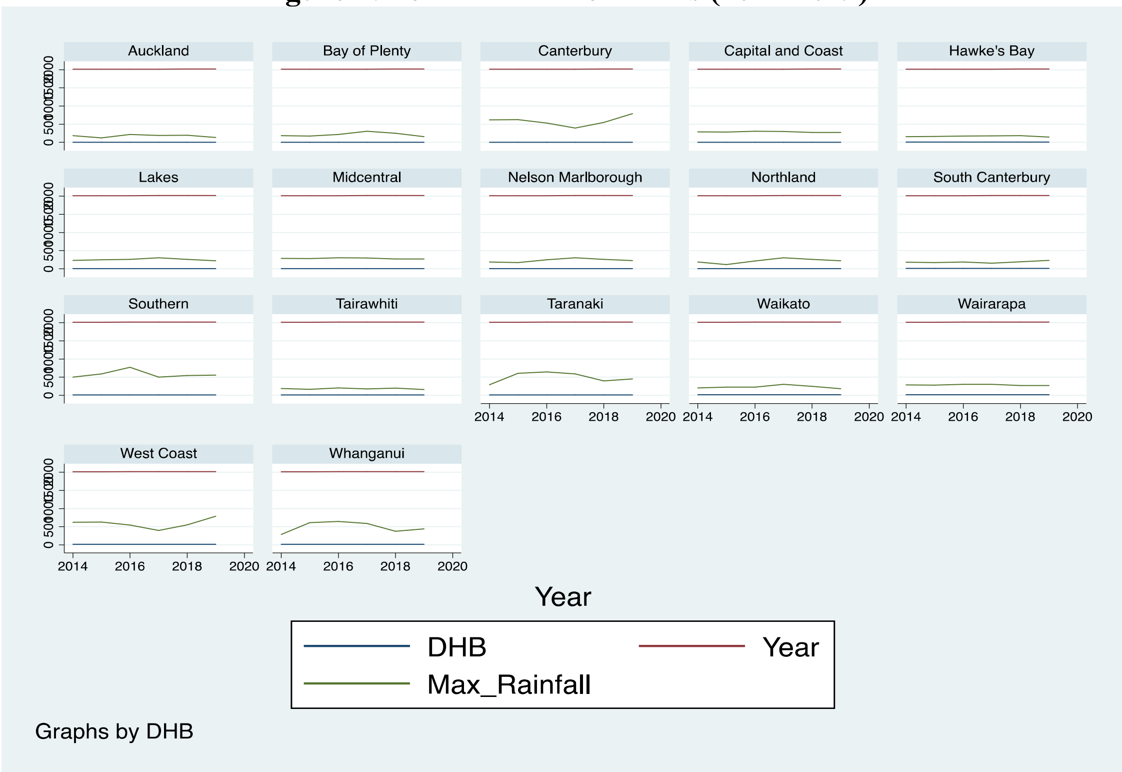
Appendix

Figure 1: Average Temperature of DHBs (2014-2019)



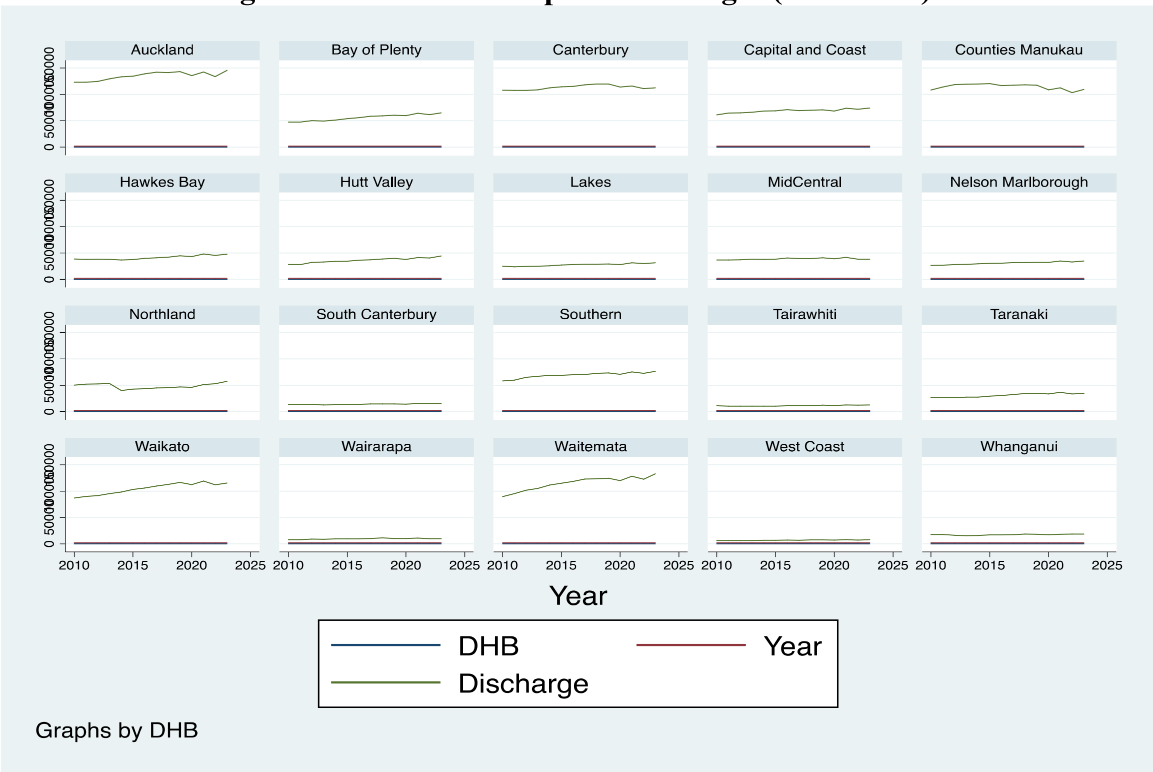
Sources: Authors' Compilation based on Data of NIWA, 2024

Figure 2: Total Rainfall of DHBs (2014-2019)



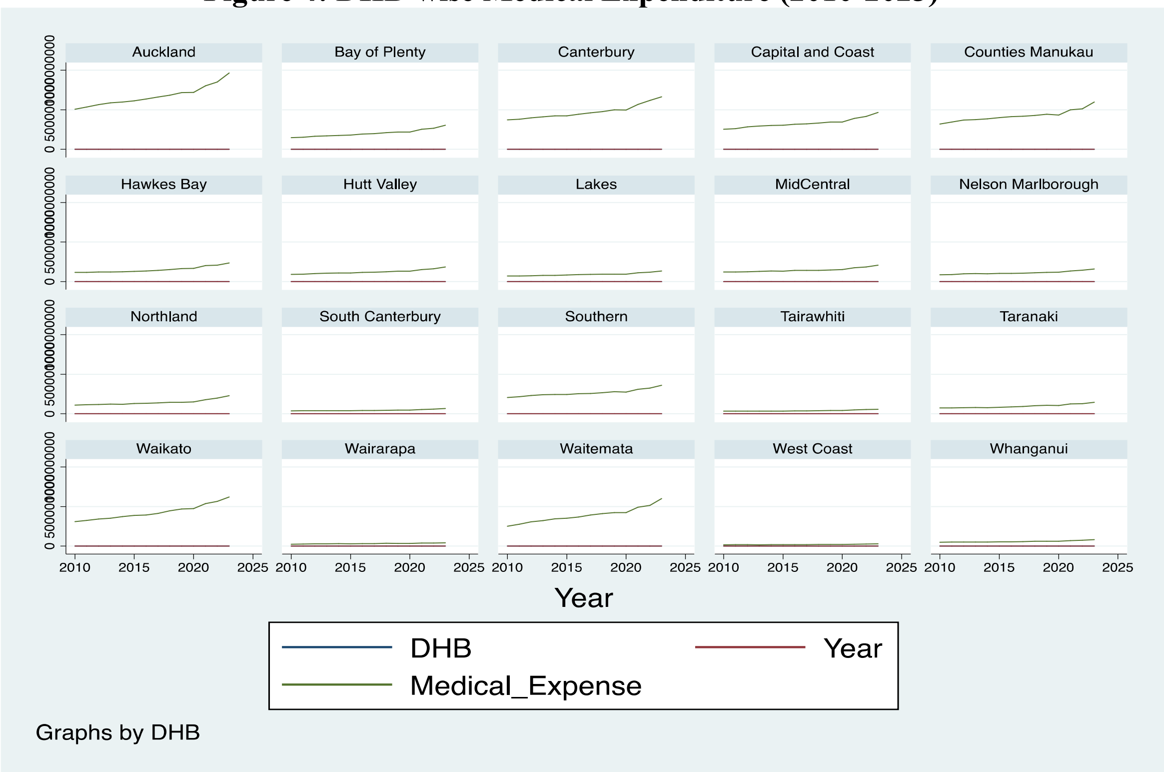
Sources: Authors' Compilation based on Data of NIWA, 2024

Figure 3: DHB-wise Hospital Discharges (2010-2023)



Sources: Authors' Compilation based on Data of Health NZ, 2024

Figure 4: DHB-wise Medical Expenditure (2010-2023)



Sources: Authors' Compilation based on Data of Health NZ, 2024

Data Sources

The author has used panel data of hospital discharge by ethnic groups, medical expenditure and weather events. All the data she utilized are accumulated from the the Ministry of Health New Zealand and the National Institute of Water and Atmospheric Research (NIWA).

The following table shows the DHBs and weather stations used for this research. There are 20 District Health Boards (DHBs) in New Zealand from which panel data (2014-2019) of hospitalization discharge rate and medical expenditure have been managed. Then, the NIWA weather stations have been identified according to the DHBs. In addition, the author has taken the data of weather events, i.e., mean temperature, maximum daily temperature, minimum daily temperature, and total rainfall from the National Climate Database of NIWA.

Table: NIWA Weather Stations under District Health Boards (DHBs)

DHB (Discharge and Medical Expenditure)	Years	NIWA Stations (Temperature & Rainfall)	DHB (Discharge and Medical Expenditure)	Years	NIWA Stations (Temperature & Rainfall)
Auckland	2014-2019	Central Auckland	Northland	2014-2019	Kaitia (North) Whangarei
Bay of Plenty	2014-2019	Tauranga	South Canterbury	2014-2019	Timaru
Canterbury	2014-2019	Lake Tekapo MT Cook Christchurch Kaikoura	Southern	2014-2019	Central Otago - Alaxandra Queenstown Lakes Dunedin Milford Sound Southland Invercargill Manapouri
Capital and Coast	2014-2019	Wellington	Tairāwhiti	2014-2019	Gisborne
Counties Manukau	2014-2019		Taranaki	2014-2019	New Plymouth
Hawke's Bay	2014-2019	Napier City	Waikato	2014-2019	Hamilton
Hutt Valley	2014-2019		Wairarapa	2014-2019	Masterton
Lakes	2014-2019	Rotorua Lakes Taupō	Waitematā	2014-2019	
MidCentral	2014-2019	Palmerston North	West Coast	2014-2019	West Port Hokitiki
Nelson Marlborough	2014-2019	Nelson Marlborough - Blenheim	Whanganui	2014-2019	Wanganui

Through NIWA and NZ Health websites and contacting with the authorities by email, the data have collected directly into excel file. Basic data cleanup has been done in order to get the data into an utilizable format. Some blank rows and columns have been discarded. In weather data, there are no stations under DHB Countries Manukau, Hutt Valley and Waitemata. These are included in Auckland and Wellington. So, the author has to exclude these DHBs from the final dataset.

From the Ministry of Health, New Zealand, the hospitalization discharges by ethnic group statistics (2014-2019) have been collected from the following links:

https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2018-30-june-2019
https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2017-30-june-2018
https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2016-30-june-2017
https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2015-30-june-2016
https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2014-30-june-2015
https://www.health.govt.nz/publication/publicly-funded-hospital-discharges-1-july-2013-30-june-2014

Author contacted with 'Harrison Devane' who is the Information Analyst of National Collection Data Services, Health New Zealand. He provided the medical expenditure data from their data records through email.

From NIWA, the statistics of mean temperature, mean maximum daily temperature, mean minimum daily temperature, and total rainfall (2014-2019) have been collected from the following link: https://cliflo.niwa.co.nz/

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