The Weather Catastrophes and Stock Market: An Impact of the Climate Change in Canada

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Abstract

In the last few decades, the frequency and intensity of extreme weather events have increased in many parts of the world, including Canada, as a result of global warming. The climate warming in Canada is about double the magnitude of global warming; therefore, the effects of weather catastrophes are expected to be higher in Canada compared to other developed economies. This study explores the impact of weather catastrophes on the Canadian stock market over the period 1988–2016. A mix of accounting ratios and statistical tests is used to estimate the effects of the extreme weather events on the Toronto Stock Exchange (TSX) composite and sub-sector indices. A significant negative effect of the weather catastrophes on stock returns is noticed a day after the extreme weather events. This effect is widespread in all sub-sectors of the market; IT and financial services sectors are the most impacted, while consumer staples is the least. It is concluded that the impact of climate warming in Canada is higher and more widespread compared to other developed economies.

JEL Classification: G14, G32, N52, Q51, Q54

Key Words: Weather Catastrophes, Global Warming, Stock Returns, Market Risk, Widespread

1. Introduction

The frequency and intensity of extreme weather events are rising due to global warming and climate change, especially in the last 40 years (Bourdeau-Brien and Kryzanowski, 2017; Francis & Vavrus, 2012). The consequences of the extreme weather events are already costing billions of dollars of losses in real property, agriculture produce, industrial production, and public infrastructure globally (Cavallo & Noy, 2011). According to the Insurance Bureau of Canada, insurers in Canada have reported increasingly larger catastrophic weather events every year across the country since 1983, and its annual cost of weather related claims has steadily increased from C$ 86 million to C$ 5 billion in 2016 (IBC, 2019; Molico, 2019). A recent Bank of Canada policy study has reported a concern that an increase in catastrophic weather events is expected to affect the Canadian financial system and overall economy (Molico, 2019). Its impact may not only be limited to the insurance, agriculture, and real estate sectors but may also affect other sectors of the Canadian economy because the warming in Canada is about double the magnitude of global warming (Bush & Lemmen, 2019).

Canada is the 10th largest economy of the world with a GDP of US$ 1.9 trillion by the end of 2019. It has the fourth largest reserves of natural resources valued at US$ 33.2 trillions as per the 2016 assessment. Canadian trade of goods and services reached C$ 1.5 trillion during 2019 (Canada, 2019). The Toronto Stock Exchange (TSX) is the world's ninth largest stock exchange with a market capitalization of over US$ 2 trillion (WFE, 2019). Any disruption in the Canadian economy could therefore impact the entire global economy. Disruption in the Canadian economy from extreme weather events has increased in the recent past. Canada is also the 10th largest emitter of greenhouse gases, which is significantly contributing both to global warming and its own climate (Bush & Lemmen, 2019). The Government of Canada has realized the economic risk of weather catastrophes and has therefore signed all major climate action accords and is committed to acting upon them in true letter and spirit. The objective of this study is to estimate the impact of weather catastrophes on Canadian investors and businesses to provide implications for future climate action policies.

The performance of an economy is very important for the stability of a country and the social well-being of its inhabitants. Stock markets are the major source of funds for stable economic growth in the modern-day economy; therefore, the performance of the stock market is complementary for the better economic performance of a country. Several research and policy studies are conducted worldwide every year to explore the various aspects of the stock market performance and economic growth. Similarly, a number of prior studies have assessed the impact of weather catastrophes on stock market returns and economic performance in various parts of the world. The weather is recognized as an influential facet of everyday life and an important variable of economic performance; therefore, a number of policy and research studies have been conducted to assess the impact of major weather events on the economy and stock market returns (Feltmate, Moudrak, Bakos, and Schofield, 2020; Wang & Kutan, 2013; Worthington & Valadkhani, 2004). Most of the studies have assessed the impact of weather catastrophes on the economy and a few have explored the relationship with stock market performance.

A study by Worthington and Valadkhani (2004) was one of the pioneer analyses to measure the impact of natural disasters on the broader Australian capital markets. They used an Autoregressive Moving Average (ARMA) to measure the impact of natural disasters from 1982 to 2002 on the Australian equity market (Worthington & Valadkhani, 2004). Their results indicate that bushfires, cyclones, and earthquakes have major effects on market returns, unlike severe storms and floods, with most effects being felt on the day of the event and in the following days. A later study by Worthington, 2008 used a GARCH model to measure the impact of natural disasters on Australian equity markets. He found the impact of natural disasters varied across regions and industrial sectors. The insurance sector was found to be more negatively affected compared to the other sectors of the market, which may be due to insurance claims from the affected areas (Worthington, 2008). Both the Australian studies assessed the impact of extreme weather events on all sectors of the Australian equity market.

The methodology of the weather impact studies improved and was tested on the data of some other markets over time. Some studies measure the impact of weather catastrophes on economic indicators of the country, while others are more focused on stock markets (Cavallo & Noy, 2011; Lanfear, Lioui, and Siebert, 2019; Wang & Kutan, 2013). A recent study by Lanfear et al. (2019) measured the impact of US landfall hurricanes on stock returns over the period 1990–2017. They calculated several accounting return ratios for different event window periods and used t-statistics to estimate the association of normal stock returns with returns during the event window period.

They found short-term returns extremely sensitive to hurricanes but long-term returns insensitive. High momentum stocks experienced a higher negative impact than other stocks. Abnormal illiquidity was another anomaly of extreme weather events.

An earlier study by Wang and Kutan (2013) compared the impact of natural disasters on the stock markets of the USA and Japan from 1989 to 2011. They used GARCH models to capture both the wealth and risk effects of natural disasters. They reported no wealth effects on the composite stock markets in either country, but there were significant wealth effects on the insurance sectors. The risk effects were felt in all markets except the Japanese composite stock market. These findings were supported by a later study by Bourdeau-Brien and Kryzanowski (2017) who further found that the negative impact of the natural disaster can be found in specific geographical regions of the USA. In these prior studies, stock markets were also taken as a proxy for the economy and the perception of investors towards weather catastrophes in informationally efficient markets. All these studies reported a significant effect of weather catastrophes on stock returns, market liquidity, and risk. However, the effect varies among regions and sub-sectors of an economy.

Recently, a number of policy studies have been conducted in Canada by various government institutions (Feltmate et al., 2020; Macklem, Chisholm, Thomassin, and Zvan, 2019; Molico, 2019) to assess the potential effects of weather catastrophes on the economy. All these studies recognized the existence of climate change risk in the Canadian economy and capital markets. Although the regulatory requirements of climate risk disclosure have been in effect since 2010, a large number of corporations are not able to disclose due to some limitations (Feltmate et al., 2020). Investors are looking for more disclosure, studies of direct financial impact, and investment tools to integrate the climate-related risk into investment management decisions (Feltmate et al., 2020; Krueger, Sautner, and Starks, 2019). A recent study by Feltmate et al. (2020) has provided some case studies and a climate risk matrix to assess the climate-related risk to various business sectors of the Canadian economy.

Several prior studies found the wealth and risk impacts of the extreme weather events on stock returns and economies, but they differ by time period, industrial sector, and geographic region. As discussed earlier, Canada is an important global economy and the impact of global warming is higher here compared to most other developed economies. However, authors of this study are not able to find any prior study which estimated the direct financial impact of the climate-related risk on the Canadian stock returns or valuation in the recent past, despite the apparent need. Moreover, some businesses and the public do not substantiate the impact of global warming on their country. Therefore, an event study methodology is used in this paper to measure the effects of extreme weather events from 1988 to 2016 on the returns of the Toronto Stock Exchange.

This study calculates the financial effects of weather catastrophes on Canadian stock returns, which corresponds with the risk perception of investors toward the increased number of extreme weather events in Canada. A significant negative price reaction of the stock market will be assumed as investors' perceptions of the risk of extreme weather events. This study contributes to the existing literature by first, being the earliest study, to the authors' knowledge, to measure the direct impact of weather catastrophes on Canadian stock returns. Second, the identification of climate-related investment risk will highlight the importance of more environmental disclosure reporting. Third, a mix of accounting and statistical methodology is used, which is familiar to stock market investors. The findings of this study are consistent with the concerns of policymakers about the higher impact of climate change on the Canadian economy. A higher and more widespread impact of the weather catastrophes on Canadian stock returns is noticed the day after (or following) the weather event. All sub-sectors of the Toronto Stock Exchange are impacted by extreme weather events except consumer staples; IT and financial services are the most impacted sectors of the TSX. Some important policy implications are discussed at the end of this study.

2. Methodology and Data Description

Most of the prior studies completed to assess the impact of weather catastrophes on the stock returns are either event-based or policy studies. The policy studies are mostly based on theoretical analysis, while event studies are based on empirical methodology. The use of the event study methodology in economics and finance literature is widespread, with landmark papers including Ball and Brown (1968) and Fama et al. (1969), who introduced this methodology to a broad audience of accounting and financial economists (Ball & Brown, 1968; Fama, Fisher, Jensen, and Roll, 1969). However, the methodology can also be found in an early study by Dolley (1938) and many later studies of the 1950s and 1960s (Corrado, 2011; Dolley, 1938). An event study is a quantitative technique that estimates the impact of specified events on stock prices. Some events impact specific firms while others are broader and may impact the whole market (Kaleem & Salahuddin, 2006; Mitchell & Netter, 1994). There are three common types of event studies in finance literature (Boehmer, Masumeci, and Poulsen, 1991; Corrado, 2011; Dutta, Knif, Kolari, and Pynnonen, 2018); the first type estimates the impact of a public events or information on the prices of individual stocks and is mostly used in legal and regulatory proceedings such as inside trading, mergers, etc. The second type disentangles the impact of a certain event or events on individual stock prices from market-wide effects. The third type of event study estimates the effect of a certain event or events on market-wide stock prices. The events investigated in the third type of event study are mostly macroeconomic, political, social, or meteorological (Henderson Jr, 1990; Mitchell & Netter, 1994). Although the effects of these events may be visible among the people and property situated in the vicinity, research studies are required to quantify the broader economic or social effects. The current study can be categorized as this type of event study, where the market-wide reaction of investors toward extreme weather events is estimated.

2.1 Data and Summary Statistics

There are two major data sets used in this study; the first data set includes natural/weather catastrophes in Canada from 1988 to 2016 and is obtained from the Canadian Disaster Database (CDD). The year 1988 is very significant in the history of climate change action plans as it was when the global community recognized the importance of climate change and established the Intergovernmental Panel on Climate Change (IPCC) under the supervision of the United Nations Environment Programme. Therefore, the year 1988 is chosen as the starting point of this study, and will extend as far as CDD data is available for, which is 2016. Either of the following criteria is adopted by the CDD to define a disaster:

- 10 or more people killed
- 100 or more people affected/injured/infected/evacuated or homeless
- an appeal for national/international assistance
- historical significance
- significant damage/interruption of normal processes such that the community affected cannot recover on its own

The CDD database includes many kinds of disasters, but only natural disasters that are considered to be the consequences of climate change are selected for this study. Trends and data of natural disasters are shown in Figures 1, 2, and 3.

Fig. 1: The Trend of Natural Disasters in Canada

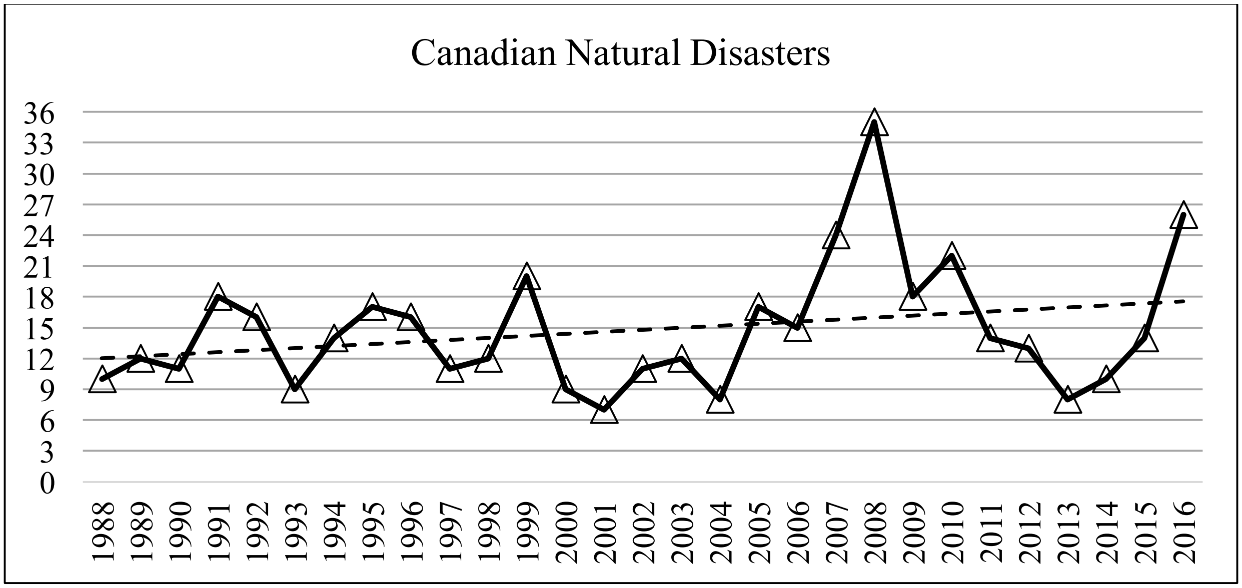
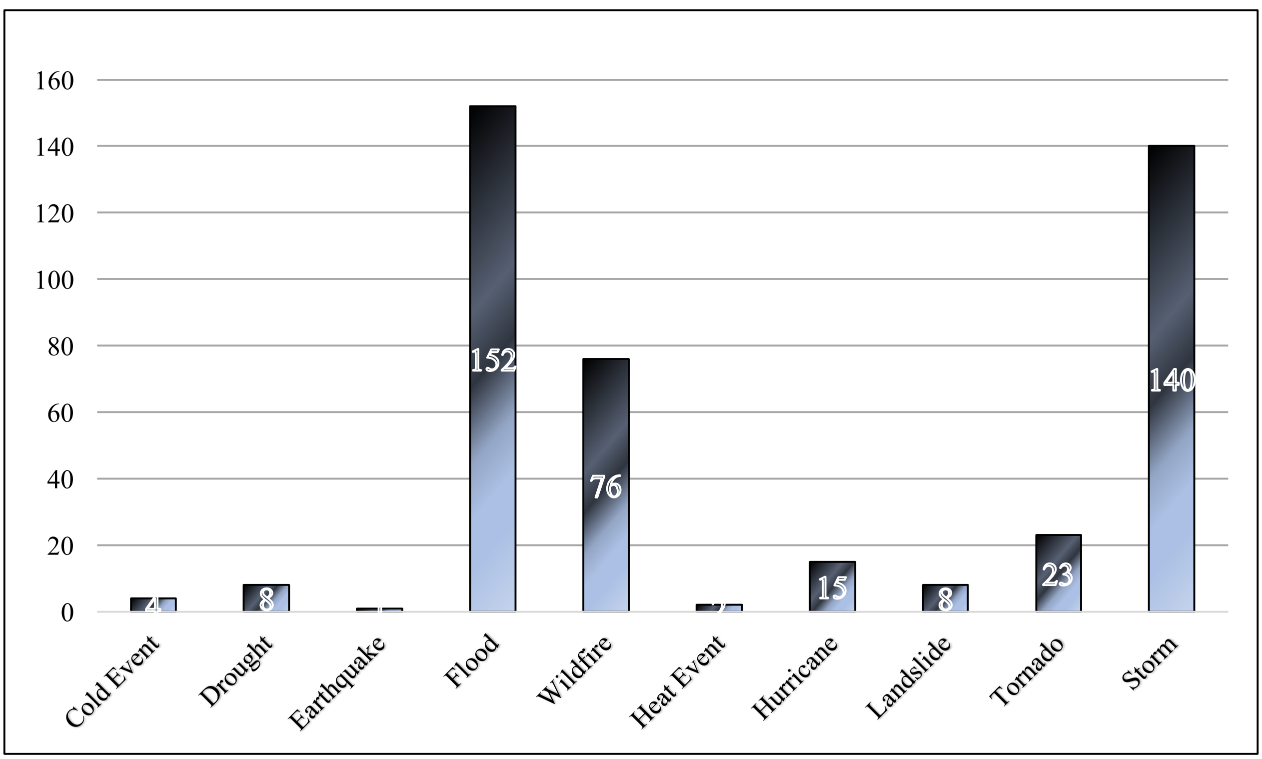
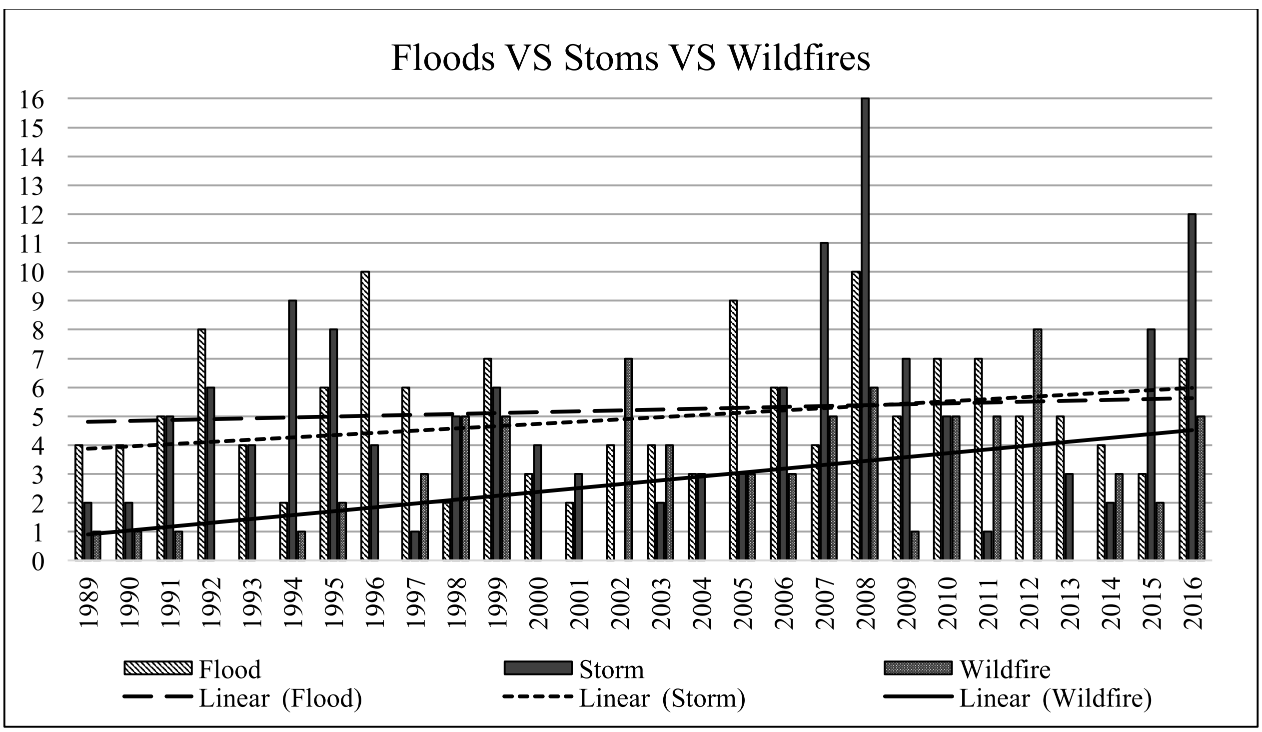


Fig. 2: Types of Natural Disasters in Canada



Although the number of natural disasters is shown to be fluctuating in Figure 1, the trend is upward during the study period, increasing from an average of 12 to 18 events a year, consistent with several climate change reports (Bourdeau-Brien & Kryzanowski, 2017; Francis & Vavrus, 2012). The numbers of weather catastrophes are shown in Figure 2, and it can be observed that the majority of disasters in a total of 429 events are floods, followed by storms and wildfires. The trend of three major types of disasters is shown in Figure 3, including the contribution of each type of weather catastrophe toward the overall trend. An increasing trend in all three major weather catastrophes is apparent from the figure. The highest increase is in the number of wildfires, followed by storms and floods. Both the intensity and frequency of wildfires have increased over the study period in Canada, especially in recent years. The changing frequency of temperature and precipitation extremes may lead to further increases in the likelihood of extreme weather events such as wildfires, floods, and droughts (Bush & Lemmen, 2019). The increasing trend of floods, storms, and wildfires in Figure 3 may be attributed to climate change. The 2013 flood in Southern Alberta and the 2016 Fort McMurray wildfire are prime examples of these extreme events in Canada, while the 2019 bush fires in Australia are a global example.

Fig. 3: Trends of Major Extreme Weather Events



The second data set is based on the closing value of the TSX Composite Index, which is based on about 250 listed companies from all 11 sub-sectors of the market and represents the 95% of market capitalization (Kapoor et al., 2018). The adjusted closing value of the TSX Composite Index and sub-sector indices obtained from The Bloomberg database for the period 1988–2016 is used for calculation of daily returns. The closing values of indices are adjusted for dividends and stock splits by the database provider. Descriptive statistics for selected indices are reported in Table 1. A significant increase in composite and sub-sector indices can be observed in the descriptive statistics. Data for 10 out of 11 sub-sector stock indices are reported, with the data for the communications index not available for the whole study period because it was formed later. The volatility and change in the indices show extreme variations over the study period, with the highest growth observed in Consumer Staples and the least in the Healthcare sector.

Table 1: Descriptive Statistics of Selected Indices

Indices	Mean	Median	SD	Min.	Max.	Change (%)
TSX Composite Index	8509.31	7880.40	3924.36	2970.34	15657.60	382.16
Consumer Disc. Index	929.65	924.41	403.27	355.84	2101.13	433.11
Consumer Staples Index	1287.60	1287.93	1068.64	216.31	4761.78	1943.30
Energy Index	1588.55	1161.09	1094.40	345.31	4239.41	541.04
Financials Index	1088.02	988.18	686.56	207.28	2622.28	1059.67
Health Care Index	731.91	585.39	530.91	208.42	3920.74	71.89
Industrial Index	1008.16	883.80	543.07	328.59	2599.89	425.73
IT Index	297.50	214.02	316.86	68.33	2307.86	169.14
Materials Index	1712.39	1411.04	847.71	739.18	4208.26	118.11
Real Estate Index	1633.83	1519.07	688.74	627.81	3238.06	76.34
Utilities Index	1210.14	1099.61	541.07	506.18	2139.12	270.10

Note: MEAN is the average index size for the trading days over the period 1988–2016; MEDIAN, Standard Deviation (SD), Minimum (MIN), and Maximum (MAX) are of each index over the same period, and CHANGE is the percentage change in the index from the first trading day of Toronto Stock Exchange (TSX) in 1988 to the last trading day in 2016.

2.2 Estimation Methodology

There are two major categories of estimation methodologies being used in prior studies to estimate the associations in event studies; the first category of studies used more sophisticated models such as Capital Asset Pricing Model (CAPM), GARCH, ARMA, etc. (Bourdeau-Brien & Kryzanowski, 2017; Wang & Kutan, 2013; Worthington & Valadkhani, 2004). The second group applied a simple methodology of calculating stock returns and used parametric or non-parametric statistical tests to estimate association among selected variables (Kaleem & Salahuddin, 2006; Lanfear et al., 2019; Maynes & Rumsey, 1993). The results of the first category are more robust and required some prior knowledge of econometrics to understand. The outcomes of the second category are easier to comprehend. This study can be placed in the second category based on methodology because its objective is to identify the potential risk of climate change to average investors who may not have the sophisticated knowledge of econometrics to understand the outcomes.

The first step of this methodology is to calculate stock index return with the following formula of DAR (Daily Average Return):

$$DAR_{mt} = \frac{1}{n}\sum_{t}^{n} R_{mt} \qquad (1)$$

Where R_{mt} is the daily return for the TSX Composite Index for 7,284 transaction days for the period 1988–2016, and *n* is the number of transaction days during the study period. The period over which the impact of disasters is observed varies in prior studies from 3 to 250 days, depending on the objectives of the study. This study has selected a period of 5 days to observe the immediate response of the investors toward the weather catastrophes. Similar to equation (1), the following formula is used to calculate the daily average return during the disaster's influence period:

$$DAR_{it} = \frac{1}{i}\sum_{t}^{i} R_{mt} \qquad (2)$$

Where i = 0, -1, -2, -3, -4, the days of event influence period, 0 is the day of the event and -4 is day four after the event and R_{mt} is the daily market return. A negative daily return on any day during the disaster's influence period will show the existence of weather catastrophe risk for investors.

The second step of the methodology is to estimate the association between daily market return and daily return during the period influenced by the disaster, which will complement the findings of the first step. Initial statistical tests showed that data is not normally distributed, and therefore the non-parametric Wilcoxon Signed-Rank test is used to estimate the association between market and event period returns. Quarterly average market returns and quarterly average event period returns are calculated for the paired-sample association test with the following formulas:

$$QAR_{mt} = \frac{1}{q} \sum_{t}^{q} R_{mt} \qquad (3)$$

Where QAR_{mt} is quarterly average return, R_{mt} is the daily market return of the TSX Composite Index and q is the number of transaction days during the quarter. Similarly, the quarterly average return of the event period is also calculated with the following formula:

$$QAR_{it} = \frac{1}{i} \sum_{t}^{i} R_{mt} \qquad (4)$$

Where QAR_{it} is the quarterly average return on event days; i is the number of event's transaction days in a quarter; and R_{mt} is the daily market return.

Similar calculations are done for each sub-sector of the TSX Composite Index (see the previous section and Table 1). The objective of calculating the returns of each sub-sector index is to identify the sector-specific influence of the weather catastrophes. Most previous studies identified the direct impact on the insurance sector and indirect impact of the policies and regulations in energy, materials, and consumer discretionary sectors (Krueger et al., 2019; Wang and Kutan, 2013); however, impacts are expected in some other sectors in Canada due to the higher rate of climate warming.

3. Results and Discussion

Calculated daily average returns of the TSX Composite Index for each day of the event-period and related statistics are reported in Table 2. There were 7,284 trading days during the study period 1988–2016, and 389 event days. Although we identified 429 extreme weather events during the study period, some study days showed more than one extreme weather event and the number of event days is therefore lower. There is no visible negative impact of the natural disaster on the returns of stocks on the event day, but a visible negative impact can be observed on the following day. All events are reported by CDD at midnight, which is before opening the market on the event day, meaning that there is no time-delay in reporting. Many prior studies have reported a delayed impact of the natural disasters on stock returns for the following reasons: first, it takes time to ascertain likely losses associated with the event; second, lags in the dissemination of information from the disaster area; and third, delays in forecasting possible effects for firms, industries, and the market as a whole (Wang & Kutan, 2013; Worthington & Valadkhani, 2004).

Table 2: Daily Average Return

Indices	Obs.	Mean	SD	Min.	Max.
TSX Composite (R_T)	7285	0.0264	0.98	-9.32	9.82
Day of Event (R_0)	389	0.0597	0.93	-6.93	2.55
Next Day (R_{-1})	389	**-0.0469**	**1.02**	-5.49	4.18
Second Day (R_{-2})	389	0.0261	0.87	-2.86	3.49
Third Day (R_{-3})	389	0.1009	0.89	-6.95	3.42
Fourth Day (R_{-4})	389	0.0293	0.94	-3.61	7.03

Note: MEAN is the average daily return of Toronto Stock Exchange (TSX) Composite Index and each day of event periods for the trading days from 1988 to 2016; Standard Deviation (SD), Minimum (MIN), and Maximum (MAX) for TSX index and each day of event periods from 1988 to 2016.

In the Canadian market, this delay may be due to any or all of these reasons, but the lag is less than most of the other markets reported in prior studies, which range from 3 to 40 days (Bourdeau-Brien & Kryzanowski, 2017; Wang & Kutan, 2013). The shorter lag in the impact of weather catastrophes implies either that the Canadian market is more informationally efficient, or that investors are more worried by the negative consequences of weather events in Canada. Although the loss of 0.0469% is recovered in the subsequent 2 days, the initial negative reaction of the investors is apparent. Another interesting observation in Table 2 is the higher standard deviation the day after the event, which implies that the increase in the level of market risk is in response to the natural disaster. A negative impact of the natural disasters on stock returns and market risk is visible in reported results. The statistical significance of this negative reaction of the market is reported in Table 3.

Table 3: Association Test Results

Variables	Quarterly Average Returns (%)						
	Obs.	**Mean**	**SD**	**Median**	**Skewness**	**Kurtosis**	**K-S Test**
TSX Index (R_T)	104[‡]	0.0227	0.12	0.0470	-1.06	1.76	0.03
Day of Event (R_0)	104	0.1098*	0.53	0.0787	-0.14	1.34	0.00
Next Day (R_{-1})	104	**-0.0956***	**0.69**	**-0.0390**	-1.24	7.98	0.00
Second Day (R_{-2})	104	0.0742	0.62	0.0343	2.44	12.15	0.00
Third Day (R_{-3})	104	0.1564**	0.60	0.1000	1.14	6.59	0.00
Fourth Day (R_{-4})	104	**0**.0168	0.62	0.0762	-1.98	11.77	0.00

Note: * and ** are significant at 10% and 5% in the Wilcoxon Signed-Rank Test, which is conducted with SPSS.[‡] Only 104 quarterly observations are selected out of a total 116 that have some extreme weather events. MEAN is an average quarterly return for event days over the period 1988—2016; STANDARD DEVIATION (SD), MEDIAN, SKEWNESS, KURTOSIS, and Kolmogorov-Smirnov (K-S) are also estimated for the study period.

The data of stock returns are calculated for the same sample of the firms on different days during the study and event periods. Therefore, related/paired sample tests of the association are used, which wasn't possible on daily returns due to the different number of observations. The quarterly average returns are calculated for the study period and event days to obtain the same number of observations for proposed tests. Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) tests are conducted to confirm the non-normal distribution of the data. Results of the K-S test, which are consistent with the S-W test, are reported in Table 3. The measures of median, skewness, and kurtosis are also provided to support the outcomes of the K-S test. The earlier outcome of the negative effects of the natural disaster on daily stock returns and volatility are further confirmed in quarterly returns and found significantly different from overall market estimates. The negative quarterly effect is higher than the daily effect and volatility has reduced as expected due lower number observations. The negative effect on mean returns is further complemented with negative median quarterly returns. The average quarterly accounting loss of 0.0956 % is substantial for the market investors, moreover, it is statistically significant too.

Table 4: Total Returns

Variables	Obs.	Cumulative Daily Returns (%)
TSX Index (R_T)	7,285	191.68
Day of Event (R_0)	389	23.22
Next Day (R_{-1})	389	-18.24
Second Day (R_{-2})	389	10.14
Third Day (R_{-3})	389	39.25
Fourth Day (R_{-4})	389	11.39

Note: Observations (Obs.) are the number of trading days for the TSX index and the number of event days for others during the period 1988–2016. Cumulative Daily Returns are a sum of all negative and positive daily returns of trading and event days.

The earlier reported negative effect of the weather catastrophes on the daily and quarterly stock returns is accumulated in Table 4 to approximate the total market loss from weather effects. The Canadian stock market lost an 18.24% return due to the extreme weather events during the period 1988–2016. The average market capitalization of the Canadian stock market during this period was approximately US$ 1.21 trillion (WFE, 2018). We estimate the dollar amount of loss by multiplying the 18.24% loss with average market capitalization to get US$ 221 billion, which is about 20% of the average Canadian GDP during 1988–2016 (WorldBank, 2018). The average GDP growth of the Canadian economy was 2.58% during the study period (WorldBank, 2018) and the average GDP loss due to weather catastrophes is about 0.70%, as calculated in this study. The outcomes of reported results are consistent with several policy studies that hint at the possibility of billions of dollars of loss to the Canadian economy due to climate warming or increase in the intensity and frequency of weather catastrophes (Macklem et al., 2019; Molico, 2019). The other objective of this study is to identify the sub-sectors of the Canadian stock market that are most or least impacted by the weather catastrophes during the study period, which are reported in Tables 5 and 6.

Table 5: Daily Average Return (Sub-Sector Indices)

Indices	Mean	Median	SD	Skew	Kurtosis	K-S Test	Min.	Max.
TSX Composite	0.0264	0.0658	0.98	-0.55	10.57	0.00	-9.32	9.82
Consumer Disc.	0.0272	0.0475	0.91	-0.25	4.20	0.00	-7.21	5.57
Consumer Staples	0.0445	0.0444	0.76	-0.01	4.31	0.00	-5.14	6.98
Energy	0.0355	0.0445	1.37	-0.21	9.06	0.00	-12.64	13.77
Financials	0.0397	0.0444	1.10	0.16	12.31	0.00	-12.01	12.06
Health Care	0.0261	0.0113	1.90	-1.64	43.19	0.00	-42.07	17.52
Industrial	0.0297	0.0447	1.14	-0.22	4.55	0.00	-7.74	8.83
IT	0.0375	0.0249	2.16	-0.55	12.03	0.00	-26.68	16.13
Materials	0.0228	0.0118	1.55	-0.07	11.92	0.00	-17.20	18.99
Real Estate	0.0146	0.0166	1.13	-0.18	5.71	0.00	-10.56	8.82
Utilities	0.0216	0.0297	0.85	-0.25	6.48	0.00	-7.45	6.32

Note: MEAN is the average daily return of Toronto Stock Exchange (TSX) Composite and each sub-sector indices for the trading days over the period 1988–2016; MEDIAN, Standard Deviation (SD), Skewness (SKEW), KURTOSIS, Kolmogorov-Smirnov (K-S), Minimum (MIN), and Maximum (MAX) for same indices and time period.

The data for daily average market and sub-sector returns as well as key statistics are reported in Table 5, which will help to better understand the later results. During the study period, the daily average return of the TSX Composite Index is 0.0264%. Returns of the consumer staples index are highest while real estate is lowest among all sub-sector indices. The estimated standard deviation shows that the consumer staples index has the lowest fluctuation, and information technology the highest. The relationship between returns and risk of the sub-sectors is not consistent with the Capital Asset Pricing Model (CAPM) of portfolio management. There is a major difference in mean and median values of TSX and sub-sector indices, which is supported with values of skewness, Kurtosis, and KS tests, from which selected data is not normally distributed. Therefore, non-parametric tests are used in Table 6 to seek an association between the returns of the TSX and sub-sector indices during the event period to assess if sub-sectors responded differently than the TSX Composite Index.

Table 6: Daily Average Return (Sub-Sector Indices)

Variables	Returns	R0	R-1	R-2	R-3	R-4	Total Effect
TSX Composite Index							
DAR	0.0265	0.0597	-0.0469	0.0261	0.1009	0.0293	
Total Returns	191.68	23.22	-18.24	10.14	39.25	11.39	-18.24
1. Information Technology							
DAR	0.0373	0.0240	-0.0717	0.1309	0.1489	-0.0925	
Total Returns	272.21	9.40	-28.10	51.30	58.36	-36.25	-64.35
2. Financial Services							
DAR	0.0397	0.0441	-0.0355	-0.0448	0.1757	0.0008	
Total Returns	289.56	17.31	-13.92	-17.58	68.86	0.31	-31.50
3. **Energy**							
DAR	0.0355	0.0080	-0.0676	0.0642	0.0570	0.0327	
Total Returns	256.42	3.12	-26.49	25.18	22.35	12.82	-26.49
4. Health Care							
DAR	0.0260	-0.0018	-0.0012	0.0183	0.1128	-0.0588*	
Total Returns	189.96	-0.70	-0.47	7.16	44.23	-23.06	-24.23
5. Basic Materials							
DAR	0.0228	0.1189	-0.0557	0.0122	0.0125	0.0845	
Total Returns	166.41	46.62	-21.85	4.77	4.89	33.14	-21.85
6. Utilities							
DAR	0.0215	0.0509	0.0052	0.0072	0.0144	-0.0390*	
Total Returns	157.21	19.94	2.02	2.81	5.66	-15.28	-15.28
7. Real Estate							
DAR	0.0144	0.0024	0.0061	0.0505	0.0998	-0.0354*	
Total Returns	105.71	0.93	2.38	19.81	39.11	-13.88	-13.88
8. Consumer Discretionary							
DAR	0.0272	0.0184	-0.0287	0.0119	0.1354	0.0482	
Total Returns	198.61	7.22	-11.27	4.67	53.08	18.90	-11.27
9. Industries							
DAR	0.0297	0.0510	-0.0072	0.0423	0.1901	0.0397	
Total Returns	215.12	20.00	-2.83	16.60	74.52	15.57	-2.83
10. Consumer Staples							
DAR	0.0445	0.0960	0.0019	0.0339	0.1106	0.0632	
Total Returns	323.91	37.62	0.73	13.28	43.37	24.77	0.00

Note: * is significant at 10% in the Wilcoxon Signed-Rank Test, which is conducted with SPSS. DAR is the daily average return from 1988 to 2016; RETURNS are the total sum of daily returns for the whole index over the period 1988–2016. Total effect is the total negative effect during the event period.

Daily average returns for each index and for event days are reported in Table 6. The sub-sectors are ranked in order of highest to lowest impacted by weather catastrophes. Moreover, the Wilcoxon Signed-Rank Test of association is applied between the TSX market and sub-sector returns to assess if the effects of extreme weather events on sub-sectors were different from the overall market. The highest effect of extreme weather events is observed in the information technology sector, which lost about 65% of returns during the event period. The initial impact came on the day after the event and was again realized on the fourth day, which is consistent with prior studies that showed technology stock fluctuates against any market event more than the rest of the market (Bennett & Wei, 2006; Schwert, 2011).

The financial services sector is ranked second-highest in terms of the effects of extreme weather events at a 31.5% loss of returns, which is expected due to insurance claims and potential problems for banks in collecting loan payments. This effect is more prolonged compared to other sectors because some effects of the weather catastrophes can be realized immediately, and the rest may come later once victims file their claims. Consumer staples is least affected among all sectors, with returns close to zero on the day following the event, which is expected because the demand for food necessities may not be significantly affected by such events. The rankings of the remaining sectors also make sense due to their relationships with weather catastrophes and global warming.

Consistent with earlier findings, the effects of weather catastrophes become apparent the day after the events and are not significantly different from the TSX composite index except for utilities, healthcare, and real estate sectors. Although the effects of the extreme weather events are realized in these three sectors too, they are delayed. This can be expected from the nature of the business of these three sectors. It takes time to estimate the actual loss of property of utility companies and of real estate. Therefore, stock returns of these sectors declined in the following two days after the events due to disruptions in their services; the decline became more profoundly evident once data on actual losses became available. It may be concluded that the effects of weather catastrophes on the Canadian market can be observed on the day following the events, and are consistent in most of the market sub-sectors. The findings are consistent with the expectations that the effects of weather catastrophes in Canada may be higher and more widespread compared to most of the developed economies because warming in Canada is higher than global warming.

4. Conclusion and Implications

This study provides evidence of the impact of weather catastrophes on stock market returns in Canada. The data consist of the daily stock returns of the TSX composite and sub-sector indices, along with the extreme weather events occurring in Canada between January 1988 and December

2016. A method mix of accounting ratios and statistical tests is used to evaluate the effects of extreme weather events on stock market returns. The most important finding of this study is that the shocks provided by weather catastrophes influence market returns and risk. The most significant negative impact is observed on the next day following the weather event and it persists in most of the sub-sectors. The volatility in market returns also increases on the day following the events and exists in daily as well as quarterly returns. The sub-sectors of IT and financial services are the most, and consumer staples the least impacted by the weather catastrophes. The negative effects of the weather events are found to lag by a few days in real estate and utility sectors. The negative impact of the weather catastrophes is higher and more widespread in Canada compared to other developed economies (Wang & Kutan, 2013; Worthington & Valadkhani, 2004).

There are several ways to expand on this work, where the impact of specific weather events in specific regions can be estimated. Some macroeconomic impact of the weather catastrophes is calculated in this study, but it can be further extended to cover other major Canadian macroeconomic indicators. This study has estimated the impact of extreme weather events on overall market returns, but it can be extended to assess the impact on market liquidity, small or large capital stocks, and for a longer period of time. Further research is required to integrate climate risk into the stock valuation models.

Better meteorological forecasting and emergency management are helping to mitigate the adverse impact of weather catastrophes; however, there is a need to implement effective climate action plans to reduce the number of human-originated weather catastrophes. In the short run, it is very important for financial regulators and policymakers to communicate and enforce the climate risk corporate disclosure for investors. An initiative is needed to educate individual and institutional investors about the climate risk corporate disclosure, sources of natural disaster information, and climate action plans.

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