Climatic Variations and the Market Value of Insurance Firms

Bin Hu¹ and Ross McKitrick²

Abstract: Major insurance and reinsurance firms have expressed concern that global warming poses economic threats to the industry due to increased risk of extreme weather events. Past studies have examined the connection between global warming trends and the value of insured damages. In principle, if weather-related threats are increasing, insurance firms may face higher payouts, but they may also enjoy an expanded market for insurance products. If they are able to price the new risks appropriately they may even end up better off. This study examines whether climatic variations have historically been connected to the profitability of insurance firms. We form a portfolio of insurance firms and then estimate a three-factor model augmented with climate variables of interest. Short-run relationships between climatic variables and insurance firms indicate that temporary deviations have small but likely beneficial effects on insurance firms. Overall, our results suggest that the past increases in extreme weather conditions have not had a negative effect on the market value of insurance firms. [Key words: global warming, climate variations.] Insurers JEL classification: G22, Q54

INTRODUCTION

Numerous recent publications from and about the insurance industry have warned of increased economic risks due to global warming. The Insurance Journal (2005) warned, “Unless insurers and their regulators take steps to address this growing challenge, all will suffer even greater financial losses in the future.” The Association of British Insurers warned of a doubling or tripling of future insured losses due to global warming (ABI

¹Corresponding author, School of Public Finance and Public Policy, Central University of Finance and Economics; Beijing Insurance Research Institute, Beijing, China, hubin1981@hotmail.com.

²Department of Economics and Finance, University of Guelph, 50 Stone Road East, Guelph, Ontario, Canada, N1G 2W1, rmckitri@uoguelph.ca.

The authors would like to thank Mike Hoy for helpful suggestions.
European insurer Allianz expressed concern that global warming could increase losses due to extreme weather events by 37 percent within a decade (Allianz, 2007). Munich Re noted that weather-related natural catastrophes have increased in both intensity and magnitude, thus raising the number of claims they pay out (WTI, 2008). Another global survey of insurance firms concluded, “Mainstream insurers have increasingly come to see climate change as a material risk to their business” (Mills, 2007). Lloyd’s latest report from Insurance Journal (Insurance Journal, 2014) stated: “changes in climate have the potential to affect extreme weather events, which subsequently impact on insurance being underwritten in the Lloyd’s market; the 20 centimeter sea level rise caused by superstorm Sandy in 2012 increased losses by 30 percent in New York alone” (www.insurancejournal.com/news/international/2014/05/08/328595.htm).

From the economic perspective, global warming and any ensuing catastrophe risk may lead to increased costs for insurance firms. As pointed out by Charpentier (2008), the central limit theorem (based on independence of claims) that helps to decide premium calculation is no longer appropriate in the face of an increased likelihood of natural catastrophe. These risks are exacerbated if regulatory intervention in the property insurance market restricts the ability of insurers to adapt to changes in the risks they choose to bear, but an increased likelihood of extreme weather-related catastrophes also complicates the process of regulatory reform. “The balancing of market and financial regulatory objectives is especially relevant to catastrophe risk—less stringent solvency requirements can increase the supply of insurance, but insurers ‘on the margin’ can be exposed to greater default risk.” (Wharton, 2008, p. 35).

In addition to the claims from insurance industries, climate change has been considered as an important factor for increased losses to the insurance industry by some academic researchers. Dlugolecki (2008) estimated that climate change has been a major source of increasing costs for insurers since 1950 and projects that the economic cost of weather damage to the globe could reach over 1 trillion USD in a single year by 2040. Kunreuther and Michel-Kerjan (2007) investigated the evolution of insured losses due to weather-related disasters and the capacity of the insurance industry to handle large-scale events. They found that the insured losses continued to increase in the period from 1970 to 2005 and reached a peak in 2005 with the occurrence of Hurricane Katrina. In addition, of the 20 most costly (in real terms) events for the insurance sector over this 35-year period, 10 occurred during the final 5 years. Kunreuther and Michel-Kerjan point out that there remains great uncertainty as to whether global warming increases weather-related catastrophes and what the key drivers are leading to the increase in large losses. Shin (2006) observed that such losses
have already led to the complete unavailability of private insurance in some storm-prone regions of the United States.

It is not surprising to see that climate change, combined with societal change such as economic development and population growth, notably in vulnerable regions, can cause insured losses of the insurance companies to increase over time. However, what is not so clear is how the value of insurance firms can be affected. A natural disaster may have two opposing effects on the stock prices of insurance companies: a negative effect is just the payments on claims, while a positive effect may be a potential increase in the market demands for their insurance products and the expectations of higher future premiums. In the long term, Maynard (2008) cautioned that all sides of the balance sheet for the insurance company could be hurt because part of the insurer’s capital is invested in equities and possibly property, which may be adversely affected by climate change; at the same time, the capital requirements are likely to increase with more frequency of extreme weather conditions. In addition, future new business is strongly related to the reputation of insurers, which could also be enhanced or damaged by climate change, so the insurance companies will be affected by climate change in a number of ways. Therefore, the objective of this paper is to determine whether measures of climatic variability have had a negative effect on the value of insurance firms up to now.

We do not measure climate change directly since the connection between global warming and extreme weather remains uncertain. Vecchi et al. (2008) argue that the question of whether there is a causal connection between global warming and Atlantic hurricane activity depends on whether Atlantic hurricane activity is more affected by absolute sea surface temperature (SST) or relative SST (i.e., the mean temperature in the hurricane development region of the tropical Atlantic relative to the entire tropical Atlantic), a question that cannot be settled with existing data. Knutson et al. (2008) used a regional climate model of the Atlantic basin to reproduce the pattern of hurricane counts between 1980 and 2006. But when faced with large-scale changes consistent with twenty-first-century projections they forecast a reduction in tropical storm and Atlantic hurricane frequency. However, Durack et al. (2012) found global warming could accelerate the cycle of evaporation and rainfall over the oceans, which may be a strong indicator of higher potential for extreme weather in the coming decades. Their study implies that more droughts and floods could occur as the water cycle may quicken by almost 20% later in this century due to global warming. The latest IPCC report (Hartmann et al., 2013) concluded that there have been more increases in the number of heavy precipitation events than decreases in most regions since 1951. In addition, IPCC found no evidence that annual numbers of tropical storms, hurricanes, and major
hurricanes have increased over the past 100 years in the North Atlantic basin, while in the same region, the frequency and intensity of the strongest tropical cyclones did increase since the 1970s.

Past studies have also examined stock price responses to extreme events, but most focus only on a single extreme event. Lamb (1998) and Angbazo and Narayanan (1996) studied how a hurricane affected insurer stock prices by focusing on the timing of hurricane landfall. Later, instead of defining the event simply as the date of landfall, Ewing et al (2006) investigated how the stock prices of insurance firms behaved before, during, and after Hurricane Floyd by taking storm characteristics fully into account. Insurer stock prices are affected by not only the expectations of strength associated with a windstorm, but also the actual damages it caused. The true losses of insurers could be close to the expectations, but windstorms may not fully develop into hurricanes or the storm may change direction, in which case the expenditures of insurers could be less than expected.

In our study, instead of looking at the effects on insurers’ stock prices of only one single extreme event, we will use multiple climate indicators aggregating extreme events over time and examine their relationships with market returns of share prices of the world’s largest reinsurance and insurance firms. To our knowledge, this is the first empirical paper to undertake a direct investigation of whether the market value of insurers is related to climatic indicators. We adopt a portfolio of insurance firms and then estimate a three-factor model plus the climate variables of interest to investigate the impact of climate trends on the market return of share prices of insurance firms. The three-factor model is well established in financial economics and has been found to perform well in predicting excess returns in stock markets (Fama and French, 1993, 1996; Chen and Zhang, 2010). We find that the insurance industries do not appear to be adversely affected by weather variations and may even benefit from them.

The remainder of the paper is organized as follows. In Section 2 we will present the data used in this paper. Our estimation strategy and empirical results will be discussed in Section 3. Section 4 is the conclusion.

DATA

Climate Indicators

Several different climate indicators will be utilized in our analysis. The Climate Extremes Index (CEI) and Accumulated Cyclone Energy (ACE) are direct indicators of weather patterns. We examined a measure of Solar
Cycle Strength (SCS), but it had no influence on the results and was dropped.

**The Accumulated Cyclone Energy Index**

Accumulated cyclone energy (herein ACE; see Figure 1) is a measure used by the National Oceanic and Atmospheric Administration (NOAA) to summarize the intensity of tropical cyclones and entire tropical cyclone seasons, particularly in the Atlantic basin. The latest available monthly ACE Index goes back to 1970, though prior to the use of satellites in 1977 coverage of some areas, especially the Southern Hemisphere, may have been intermittent. We will use only the post-1979 portion, so this will not affect our analysis. The ACE Index is calculated by summing the squares of the estimated maximum sustained velocity of every active tropical storm (wind speed 35 knots (65 km/h) or higher), at six-hour intervals, and approximates the energy used by a tropical system over its lifetime (Bell et al., 2000). The values of the ACE Index used herein were kindly provided to us by Ryan Maue (Maue, 2009, 2011) of the Center for Ocean and Atmosphere Prediction Studies at Florida State University.

**U.S. Climate Extremes Index**

The U.S. Climate Extremes Index (herein CEI; see Figure 2) is a monthly series first introduced in Karl et al. (1996) to summarize climate variability in the United States. The CEI is calculated back to 1910 and is provided by the National Climatic Data Center of the U.S. Department of Commerce (www.ncdc.noaa.gov/extremes/cei/index.html). It aggregates several climatic indicators including monthly maximum and minimum
temperature, daily precipitation, and the monthly Palmer Drought Severity Index (PDSI).

The CEI is reported as percentage values ranging from 0% to 100%, representing the fraction of the United States experiencing extreme weather conditions, in terms of all the climate indicators making up the CEI. The graph indicates an upward trend since late 1960s. Although CEI is only a measure for extreme weather conditions in the U.S., to the extent that extreme weather in the U.S. is induced by global trends, this will serve as a proxy for broader climatic changes. Also, both Munich Re and Swiss Re are multinational corporations with extensive U.S. exposure.

The Insurers

The insurers best suited for our study are large reinsurance companies, so we examine Munich Re and Swiss Re. They provide protection to private insurers against catastrophic losses. Reinsurers typically share a significant portion of the insured losses with the insurers. For example, half of insured losses due to Hurricane Katrina were shared by reinsurers (Kunreuther and Michel-Kerjan, 2007). In addition, large reinsurers can diversify their risk geographically and restrict their exposure in catastrophe-prone areas to keep the chances of severe losses at an acceptable level. We will also investigate the large general insurers ING and AIG, which have property exposure.

---

3Government agencies will also provide financial support to private insurers.
4Kunreuther and Michel-Kerjan (2007) found that the price of catastrophe reinsurance in the U.S. rose significantly as a result of the 2004 and 2005 hurricane seasons.
We also use the NASDAQ Insurance Index in our analysis. The NASDAQ Insurance Index is a capitalization-weighted index designed to measure the performance of all NASDAQ stocks in the insurance sector. The index was developed with a base value of 100 as of February 5, 1971. It includes full line insurance, insurance brokers, property and casualty insurance, reinsurance, and life insurance. Although part of the losses in this category are not directly linked to weather-related natural catastrophes, the relationship between the insurance index and climate indicators at least partially provides some guidance of the impact of climate change on the overall performance of insurance industries.

Our share prices for Munich Re, Swiss Re, and ING are all in euro currency and are primarily traded on European exchanges. Swiss Re is traded under the virt-x stock exchange, now known as SWX Europe as of March 3, 2008. Munich Re is traded mainly in the German stock market’s Xetra system. ING is traded both on the NYSE and the Euronext, but here

---

5In our robust analysis, we also include five other U.S. insurance companies because of the higher penetration rates in the U.S. insurance market. Furthermore, CEI is a measure for extreme weather conditions only in the U.S.

6Detailed information on components for the NASDAQ insurance index is available at http://finance.yahoo.com/q/cp?s=^IXIS.
we will use the share price from Euronext to keep in line with the Munich Re and Swiss Re share price information. For AIG, since it is traded only on the NYSE, share price is in dollars. The number of observations on each of these insurance firms depends on when they became publicly traded. The values are shown in Figure 3. In addition, the data as used in the analysis are summarized in Table 1.

**INVESTIGATING THE SHORT-RUN RELATIONSHIP BETWEEN CLIMATIC VARIABLES AND INSURANCE PRICES**

**Regression Model**

In this section we develop a regression model that allows us to look for evidence of short-run influences of weather on rates of return to insurance firms. In addition to the climate indicators, we will also include the three factors of Fama and French (1993) as additional explanatory variables to estimate the impact of climate variations on the market returns of insurance firms. Fama and French found that three stock-market factors seem to explain the average returns of the stock market: an overall market factor, factors related to the firm size, and book-to-market equity. The basic Fama-French model as follows:

\[
R - R_f = \alpha + \beta(R_{MKT} - R_f) + \beta_1SMB + \beta_2HML.
\]

Here \(R\) is the portfolio rate of return, \(R_f\) is the risk-free return rate, and \(R_{MKT}\) is the return of the whole stock market. SMB and HML measure the historic
<table>
<thead>
<tr>
<th>Variable code</th>
<th>Variable name</th>
<th>Units</th>
<th>Observations</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>Climate Extremes Index</td>
<td>%</td>
<td>408</td>
<td>18.61</td>
<td>6.73</td>
<td>5.56</td>
<td>42.20</td>
</tr>
<tr>
<td>ACE</td>
<td>Accumulated Cyclone Energy</td>
<td>$10^4$ kt$^2$</td>
<td>408</td>
<td>63.09</td>
<td>45.74</td>
<td>0.00</td>
<td>266.39</td>
</tr>
<tr>
<td>AACE</td>
<td>Atlantic ACE</td>
<td>$10^4$ kt$^2$</td>
<td>408</td>
<td>8.86</td>
<td>19.57</td>
<td>0.00</td>
<td>155.01</td>
</tr>
<tr>
<td>Swiss</td>
<td>Swiss Re share price</td>
<td>Euros</td>
<td>239</td>
<td>88.66</td>
<td>47.05</td>
<td>14.53</td>
<td>201.55</td>
</tr>
<tr>
<td>Munich</td>
<td>Munich Re share price</td>
<td>Euros</td>
<td>167</td>
<td>150.38</td>
<td>82.69</td>
<td>52.50</td>
<td>381.06</td>
</tr>
<tr>
<td>ING</td>
<td>ING share price</td>
<td>Euros</td>
<td>192</td>
<td>19.88</td>
<td>10.14</td>
<td>2.82</td>
<td>42.54</td>
</tr>
<tr>
<td>AIG</td>
<td>AIG share price</td>
<td>Dollars</td>
<td>340</td>
<td>72.83</td>
<td>30.32</td>
<td>0.42</td>
<td>150.82</td>
</tr>
<tr>
<td>Index</td>
<td>NASDAQ Index share price</td>
<td></td>
<td>408</td>
<td>1684.19</td>
<td>1425.58</td>
<td>128.74</td>
<td>4785.14</td>
</tr>
<tr>
<td>ALL</td>
<td>The Allstate Corporation</td>
<td>Dollars</td>
<td>235</td>
<td>41.81</td>
<td>15.81</td>
<td>16.83</td>
<td>96.25</td>
</tr>
<tr>
<td>ACGL</td>
<td>Arch Capital Group Ltd.</td>
<td>Dollars</td>
<td>208</td>
<td>40.59</td>
<td>22.35</td>
<td>12.62</td>
<td>104.00</td>
</tr>
<tr>
<td>AGII</td>
<td>Argo Group International Holdings, Ltd.</td>
<td>Dollars</td>
<td>314</td>
<td>31.93</td>
<td>13.72</td>
<td>8.55</td>
<td>93.00</td>
</tr>
<tr>
<td>BWINA</td>
<td>Baldwin &amp; Lyons Inc.</td>
<td>Dollars</td>
<td>319</td>
<td>22.46</td>
<td>5.08</td>
<td>12.00</td>
<td>46.00</td>
</tr>
<tr>
<td>FNHC</td>
<td>Federated National Holding Company</td>
<td>Dollars</td>
<td>170</td>
<td>8.95</td>
<td>6.22</td>
<td>1.35</td>
<td>28.18</td>
</tr>
<tr>
<td>ER$_{MKT}$</td>
<td>Rate of U.S. market excess return</td>
<td>Dollars</td>
<td>408</td>
<td>0.60</td>
<td>4.57</td>
<td>-23.24</td>
<td>12.46</td>
</tr>
<tr>
<td>SMB</td>
<td>Excess returns of small caps over big caps (U.S.)</td>
<td></td>
<td>408</td>
<td>0.18</td>
<td>3.08</td>
<td>-16.39</td>
<td>22.00</td>
</tr>
<tr>
<td>HML</td>
<td>Excess returns of value stocks over growth stocks (U.S.)</td>
<td></td>
<td>408</td>
<td>0.32</td>
<td>3.06</td>
<td>-12.60</td>
<td>13.84</td>
</tr>
<tr>
<td>EER$_{MKT}$</td>
<td>Rate of Europe market excess return</td>
<td></td>
<td>270</td>
<td>0.47</td>
<td>5.14</td>
<td>-22.14</td>
<td>13.78</td>
</tr>
<tr>
<td>ESMB</td>
<td>Excess returns of small caps over big caps (Europe)</td>
<td></td>
<td>270</td>
<td>-0.08</td>
<td>2.31</td>
<td>-6.94</td>
<td>9.31</td>
</tr>
<tr>
<td>EHML</td>
<td>Excess returns of value stocks over growth stocks (Europe)</td>
<td></td>
<td>270</td>
<td>0.40</td>
<td>2.40</td>
<td>-9.57</td>
<td>10.96</td>
</tr>
</tbody>
</table>

**Note:** All the variables are monthly data ending in December 2012. The number of observations on individual insurance firms depends on when they became publicly traded. The weather variables cover from January 1979 to December 2012.
excess returns of small capitalization firms (“caps”) over big caps and of value stocks over growth stocks, respectively. SMB is the difference between the average return rate of a small sample group and the average return rate of three large groups, which represents the risk factor involving with size effect; HML is the difference between the average return of two portfolios that have BE/ME (book to market ratio) high and average return of two portfolios that have low BE/ME.

To use a linear regression framework we need to ensure that the variables are in a stationary form. For the dependent variables, we will use the monthly excess return on the share prices of insurance industries, defined as the period \( t \) first difference divided by the period \( t \) price minus the risk-free return rate.\(^7\) This construction is stationary for all insurance firms. In addition, unit root tests suggest that both AACE and CEI are stationary processes.\(^8\) For convenience, all the variables have been transformed to standard deviation units by subtracting the mean and dividing by the standard deviation. Hence all slope coefficients have the same interpretation, namely, showing how many standard deviations the excess rate of return on the share changes in response to a one-standard-deviation change in the climatic variable.

Our empirical approach is therefore the basic Fama-French three-factor model plus climate indicators.

\[
ER_t = \alpha + \beta(ER_{MKT})_t + \beta_1SMB_t + \beta_2HML_t + A_1(L)CEI_t + A_2(L)AACE_t + \text{seasonal dummies} + \epsilon_t
\]

where \( ER_t \) and \( (ER_{MKT})_t \) represent, respectively, the excess return of insurance companies and the excess return of whole stock market. Our share prices for Munich Re, Swiss Re, and ING are all in euro currency and are primarily traded on European exchanges, so Fama-French factors for Europe will be adopted for these three insurance firms; as for AIG and the NASDAQ insurance index, since both of them are traded on the NYSE,

\(^7\)We compute monthly rates of return for the insurance companies \( (r_t) \) using the formula \( \log P_t - \log P_{t-1} \) (where \( P_t \) is the monthly closing share price at time \( t \)). For the Nasdaq Insurance Index, the original data of monthly closing share price was chosen by taking the 27th as the last day of each month.

\(^8\)Augmented Dickey-Fuller and Phillips-Perron tests are used to test for unit roots in all time series variables. The power of the Dickey-Fuller test is dramatically reduced if a series has changed exogenously at any time during the sample period (Perron, 1989). Therefore, both tests are adopted. The null hypothesis of both tests are that the time series is \( I(1) \) and the alternative is trend stationary. The null is rejected for all climatic variables.

\(^9\)Here \( ER_t = r_t - (R_f)^t; (ER_{MKT})_t = (R_{MKT})_t - (R_f)^t \).
Fama-French factors for the U.S. are used for these two regressions. a is the constant term; seasonal dummies are included to account for seasonality in the climate indicators;\(^\text{10}\) \(A_1(L)\) and \(A_2(L)\) denote the lag operators for climate variables;\(^\text{11}\) and \(\varepsilon_t\) is the residual.

**Regression Results**

In what follows we will analyze the different insurance companies one by one using a general-to-specific approach to derive the underlying empirical model. Because the time-series data is monthly and its availability is limited, at most 12 lags for each time series will be included. Cross-correlograms between dependent and independent variables are also plotted and some lag terms can be eliminated based on the magnitude of correlation. More coefficients could be eliminated guided by the standard errors of the estimated coefficients by using t-test and BIC criteria.\(^\text{12}\) The regression results of climate variables on the monthly excess return of share prices of different insurance companies and index are reported in Table 2.

(i) **Swiss Re**

Equation (3) reports the regression results for the share price of Swiss Re:

\[
\text{ER.s}wiss_t = \underbrace{0.009}_{(0.05)} + \underbrace{0.52(\text{ER}_{\text{MKT}})_t}_{(0.11)} - \underbrace{0.23\text{SMB}_t}_{(0.07)} + \underbrace{0.15\text{HML}_t}_{(0.08)} + \varepsilon_t. \quad (3)
\]

Here and in the following equations, the number in parentheses underneath the coefficient is the Newey-West standard error.\(^\text{13}\) Significance levels are shown in Table 2, where bold denotes significance at the 10 percent level, * denotes 5 percent, and ** denotes 1 percent. “ER” in the

\(^{10}\)AACE has very strong seasonal patterns, since most hurricanes are formed from May to October. In addition, the rate of return to insurance companies could also exhibit seasonal patterns if the insurance coverage cannot be diversified.

\(^{11}\)Since the payouts of insurance firms could take several months after a natural disaster, there is a time delay for these to be reflected in the balance sheets of insurance companies, in addition, the premium adjustments and the reputation could also take time to be reflected in the stock market, so the lag operators are included for the climate variables.

\(^{12}\)BIC is the Bayesian Information Criterion. BIC has been widely used for model identification in time series and linear regression. It guards against overfidding by introducing a penalty term for the number of parameters in the model.

\(^{13}\)A Newey-West estimator is used to overcome autocorrelation and heteroskedasticity in the error term of the regression model.
CLIMATIC VARIATIONS AND THE MARKET VALUE OF INSURANCE FIRMS

Table 2. OLS Estimation of the Impact of Climate Variability on the Monthly Excess Return of Share Prices of Insurance Companies (Atlantic Accumulated Cyclone Energy Index as Independent Variable)

<table>
<thead>
<tr>
<th></th>
<th>Swiss Re</th>
<th>Munich Re</th>
<th>ING</th>
<th>AIG</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>0.078*</td>
<td>0.092*</td>
<td>0.042(1)</td>
<td>0.073(1)</td>
<td>0.071(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.076*(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.094*(9)</td>
</tr>
<tr>
<td>AACE</td>
<td>0.003(9)</td>
<td>0.005(4)</td>
<td></td>
<td></td>
<td>0.004(2)</td>
</tr>
<tr>
<td>ER_{MKT}</td>
<td>0.517**</td>
<td>0.411**</td>
<td>0.638**</td>
<td>0.480**</td>
<td>0.618**</td>
</tr>
<tr>
<td>SMB</td>
<td>-0.232**</td>
<td>-0.278**</td>
<td>-0.104*</td>
<td>0.002</td>
<td>0.177**</td>
</tr>
<tr>
<td>HML</td>
<td>0.145*</td>
<td>-0.016</td>
<td>0.173**</td>
<td>0.235</td>
<td>0.255**</td>
</tr>
<tr>
<td>CONS</td>
<td>0.009</td>
<td>0.115</td>
<td>-0.263**</td>
<td>0.006</td>
<td>-0.024</td>
</tr>
<tr>
<td>R²</td>
<td>0.42</td>
<td>0.28</td>
<td>0.61</td>
<td>0.21</td>
<td>0.43</td>
</tr>
<tr>
<td>AIC</td>
<td>553</td>
<td>425</td>
<td>374</td>
<td>887</td>
<td>915</td>
</tr>
<tr>
<td>BIC</td>
<td>567</td>
<td>453</td>
<td>403</td>
<td>906</td>
<td>951</td>
</tr>
<tr>
<td>Obs</td>
<td>238</td>
<td>166</td>
<td>191</td>
<td>339</td>
<td>399</td>
</tr>
<tr>
<td>Month</td>
<td>1993.02</td>
<td>1999.02</td>
<td>1997.01</td>
<td>1984.09</td>
<td>1979.01</td>
</tr>
</tbody>
</table>

Marginal effects

<table>
<thead>
<tr>
<th></th>
<th>Swiss Re</th>
<th>Munich Re</th>
<th>ING</th>
<th>AIG</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>0.078*</td>
<td>0.092*</td>
<td>0.042</td>
<td>0.314**</td>
<td></td>
</tr>
<tr>
<td>AACE</td>
<td>0.003</td>
<td>0.005</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bold** typeface indicates significance at the 10% level; **bold** at the 5% level; **bold** at the 1% level. Month refers to the starting trading month for each insurance series; the end month is the same at December, 2012. The numbers in parentheses in the upper table indicate the lag of the climate variable. The standard error of climate variables has been adjusted by using Newey–West estimator. The significance of marginal effects of each variable represents whether they are significant as a group.

dependent variable denotes the excess rate of return. From equation (3), the variations of both AACE and CEI are not correlated with the excess return of Swiss Re. Therefore, there is no evidence that increases in extreme weather as measured by the AACE and CEI would be expected to adversely affect Swiss Re. Seasonal dummies are not included because AACE is not significant and is excluded as an explanatory variable.
In contrast to Swiss RE, the variation of both AACE and CEI have positive effects on the excess return of Munich Re, with the eighth lagged index of CEI significant with p-value = 0.049 and ninth lagged index of AACE significant with p-value = 0.1. Based on the regression results of the world’s two largest reinsurance companies, Munich Re and Swiss Re, we find no evidence that the excess rate of return of share prices negatively relates to climate indicators. Actually, there is a short-run net benefit to Munich Re with a uniform increase in CEI and AACE. Therefore, we find no evidence
of a deleterious relationship between extreme weather variables and the market excess return to reinsurance companies.

(iii) ING

The estimated regression using the share returns of ING is:

\[
\text{ER.ING}_t = \frac{0.26}{(0.10)} + \frac{0.09 \text{CEI}_{t-2}}{(0.04)} + \frac{0.005 \text{AACE}_{t-4}}{(0.003)} + 0.64(\text{ERMKT})_t - 0.10 \text{SMB}_t + 0.17 \text{HML}_t + \text{seasonal dummies} + \epsilon_t .
\]

Similar to Munich Re, the second lagged index of CEI is positive and significant with \( p\)-value = 0.025; the fourth lagged index of AACE is positive and significant with \( p\)-value = 0.087. Therefore, there is also a short-run net benefit to ING with a uniform increase in CEI and AACE.

(iv) AIG

The final regression model, for the rate of return to AIG, is:

\[
\text{ER.AIG}_t = \frac{0.006}{(0.05)} - \frac{0.04 \text{CEI}_{t-1}}{(0.02)} + \frac{0.48(\text{ERMKT})_t}{(0.14)} + \frac{0.002 \text{SMB}_t}{(0.05)} + \frac{0.23 \text{HML}_t}{(0.13)} + \epsilon_t .
\]

Only the first lagged index of CEI is positive and significant with \( p\)-value = 0.057, without the effects of AACE, so seasonal dummies are also excluded.

(v) Insurance Index

Using the market value index for the whole insurance industry we pick up many more individual effects.

\[
\text{ER.insurance}_t = \frac{0.02}{(0.07)} + \frac{0.07 \text{CEI}_{t-1}}{(0.04)} + \frac{0.07 \text{CEI}_{t-2}}{(0.04)} + \frac{0.08 \text{CEI}_{t-3}}{(0.04)} + \frac{0.09 \text{CEI}_{t-9}}{(0.04)} + \frac{0.004 \text{AACE}_{t-2}}{(0.002)} + \frac{0.62(\text{ERMKT})_t}{(0.05)} + \epsilon_t .
\]
\[
0.18 \text{SMB}_t + 0.25 \text{HML}_t + \varepsilon_t.
\]

Both CEI and AACE have significant effects on the excess return of the NASDAQ Insurance index. The first, second, third, and ninth lagged indexes of CEI are individually and jointly significant, and positively affect the excess return of insurance index. The second lagged index of AACE is also positively related with the excess return of insurance index. The \(p\)-value of joint effects across climate variables is 0.001. Hence, we can find no evidence for a negative short-run effect of weather variations on the rates of return to the NASDAQ insurance index.

Overall, except for Swiss Re, insurance firms and the insurance index exhibit sensitivity to climate variations. The marginal effects of both the CEI and AACE are significant for the Munich Re, ING, and NASDAQ insurance index, and are positively related to the excess rate of return. For AIG, only the CEI significantly and positively affects the excess rate of return. The consistency of the results provides striking evidence that insurance firms may even benefit from more tropical storms and other extreme weather events. Therefore, our results indicate that there is little evidence to suggest that losses await insurance companies due to increases in extreme weather conditions, whether or not induced by global warming.

It is possible that the weather indices themselves provide information that allows reinsurers to plan for future trends in extreme events. If this is so it would explain why the index is not negatively related to profits and why extreme weather events have in fact not had a negative impact on insurance firms. In other words, if the index suggests increased frequency of extreme weather events and that information is positively related to costs (loss ratios), but the index is nevertheless not indicating worsening profits, then this points to the usefulness of the index in helping reinsurers plan for future losses. However, even if this possibility were true, it would not change our basic finding that an increase in extreme weather is not associated with losses for insurance firms.

**Robustness Check**

In our regression analysis, we use the Atlantic Accumulated Cyclone Energy index as one indicator for climate variability. As we explained above, the insured losses for natural catastrophes would still be concentrated in the U.S. due not only to natural occurrence but also to higher penetration rates. But the insurance coverage of these big insurance companies in the Asia and South America markets has grown very quickly in
Table 3. OLS Estimation of the Impact of Climate Variability on the Monthly Excess Return of Share Prices of Insurance Companies (Global Accumulated Cyclone Energy Index as Independent Variable)

<table>
<thead>
<tr>
<th></th>
<th>Swiss Re</th>
<th>Munich Re</th>
<th>ING</th>
<th>AIG</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>0.079* (7)</td>
<td>0.112** (2)</td>
<td>0.042(1)</td>
<td>0.071(1)</td>
<td>0.073 (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.078* (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.099* (9)</td>
</tr>
<tr>
<td>ACE</td>
<td>0.082(2)</td>
<td>0.138(4)</td>
<td>0.088* (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>−0.052(6)</td>
<td>−0.092(8)</td>
<td>0.094(7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−0.089(10)</td>
<td></td>
</tr>
<tr>
<td>ER_MKT</td>
<td>0.520**</td>
<td>0.408**</td>
<td>0.642**</td>
<td>0.480**</td>
<td>0.619**</td>
</tr>
<tr>
<td>SMB</td>
<td>−0.211**</td>
<td>−0.265**</td>
<td>−0.109*</td>
<td>0.002</td>
<td>0.177**</td>
</tr>
<tr>
<td>HML</td>
<td>0.154*</td>
<td>−0.024</td>
<td>0.160**</td>
<td>0.235</td>
<td>0.251**</td>
</tr>
<tr>
<td>CONS</td>
<td>0.010</td>
<td>0.033</td>
<td>−0.249*</td>
<td>0.006</td>
<td>0.013</td>
</tr>
</tbody>
</table>

|        | 0.079* | 0.112** | 0.042 | 0.321** |
|        | 0.030  | −0.043  | 0.182** |

Bold typeface indicates significance at the 10% level; bold* at the 5% level; bold** at the 1% level. Month refers to the starting trading month for each insurance series; the end month is the same at December, 2012. The numbers in parentheses in the upper table indicate the lag of the climate variable. The standard error of climate variables has been adjusted by using Newey-West estimator. The significance of marginal effects of each variable represents whether they are significant as a group.

recent years, so we also use the Global Accumulated Cyclone Energy index (GACE) as an explanatory variable to test the consistency of our regression results, which is reported in Table 3. There is a significant and positive marginal effect of GACE on the NASDAQ insurance index, but no relationship with Swiss Re, Munich Re, ING, and AIG. Given that the insurance coverage of these insurance companies is mainly in North America and Europe, it is not surprising that there is no correlation between GACE and
the market return of insurance companies, which instead shows that AACE is more appropriate as an explanatory variable. CEI is not correlated with the excess return to Swiss Re, but significantly and positively affects the excess return to the other four insurance series. Therefore, we still find no evidence of a deleterious relationship between extreme weather variables and the market excess return to insurance companies.

To further test whether our results are robust, we investigate some other big U.S. insurance companies that have property exposure and business coverage along the east coast.\textsuperscript{14} The regression results are reported in Table 4. The CEI is significantly and positively correlated with the excess return to ALL, ACGL, AGII, and BWINA, without any effect on FNHC; the AACE significantly and positively affects the excess return to ALL and BWINA, but there is no correlation with the other three insurance companies. The case of U.S. insurance companies again supports our previous results that insurance companies may not be adversely affected by climate variations.

\section*{CONCLUSION}

Financial losses associated with extreme weather activities have been increasing in past years. Insurance companies and others have expressed concern that global warming has strengthened or will strengthen these trends. We have investigated the effect of past climatic variations on the rates of excess return of insurance companies. We find consistent evidence that changes in climate variables do induce changes in the excess return of insurance companies. With regard to rates of return on insurance and reinsurance firms, the most consistent effect is that increases in extreme climate conditions, as measured by the CEI Index, increase earnings rates in the subsequent quarter for all reinsurance and insurance companies except Swiss Re. Increases in the Atlantic Accumulated Cyclone Index are also associated with an increased rate of return to Munich Re, ING, and the NASDAQ insurance index. In addition, using the Global Accumulated Cyclone Index as an explanatory variable or including more U.S. insurance firms in our analysis, we still find strong evidence to support our results.

Overall, we find no evidence that increases in standard measures of extreme weather have a negative effect on the excess return of major insurance firms. Instead, firms may simply be finding profitable ways to

\textsuperscript{14}These five insurance companies are The Allstate Corporation (ALL), Arch Capital Group Ltd. (ACGL), Argo Group International Holdings, Ltd. (AGII), Baldwin & Lyons Inc. (BWINA), and Federated National Holding Company (FNHC).
respond to changing market conditions. Our findings indicate that as property owners look to the insurance industry to help adapt to risks associated with climate change, the industry itself will not be adversely affected as it meets this need.
REFERENCES


