

Climatic Variations and the Market Value of Insurance Firms

Bin Hu¹

School of Public Finance and Public Policy
Central University of Finance and Economics
BeiJing, China

Ross McKittrick²

Department of Economics & Finance
University of Guelph
Guelph Canada N1G 2W1

October 1 2015

Forthcoming: *Journal of Insurance Issues*

Key words: Global Warming, Climate Variations, Insurers

JEL Classification: G22, Q54

¹Corresponding author: Bin Hu, School of Public Finance and Public Policy, Central University of Finance and Economics, BeiJing, China, 100081. Phone: 0086-10-62288202; Fax: 0086-10-62288202; E-mail: bhu@cufe.edu.cn.

²Department of Economics & Finance, University of Guelph, 50 Stone Road East, Guelph, Ontario, N1G 2W1. Phone: 519-824-4120 ext.52532; Fax: 519-763-8497; E-mail: rmckitri@uoguelph.ca.

Climatic Variations and the Market Value of Insurance Firms

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.

1. 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 2007). European insurer Allianz expressed concern that global warming could increase losses due to extreme weather events by 37 percent within a decade

<http://www.ceres.org/Page.aspx?pid=858>). 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 2009). Lloyd’s (2014) latest report stated that “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 super storm Sandy in 2012 increased losses by 30 percent in New York alone.” <http://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) estimates 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 (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 the insured losses continue to increase in the period from 1970 to 2005 and reached its 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 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 the societal change such as economic development and population growth, notably in vulnerable regions, can cause insured losses of the insurance companies 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 due to the potential increasing of 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 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 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 the 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 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 forced 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 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, 2014) 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 1970s.

Past studies have also examined the stock price responses to extreme events, but most are focusing only on a single extreme event. Lamb (1998) and Narayanan (1996) studies 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 (2005) investigated how the stock prices of insurance firms behaved before, during and after Hurricane Floyd by fully taking storm characteristics into account. Insurer stock prices are not only affected by 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, however 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 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.

2. Data

2.1 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 so it was dropped.

2.1.1 The Accumulated Cyclone Energy Index

Accumulated cyclone energy (herein ACE, 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 is 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 only use 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 2013) of the Center for Ocean and Atmosphere Prediction Studies at Florida State University.

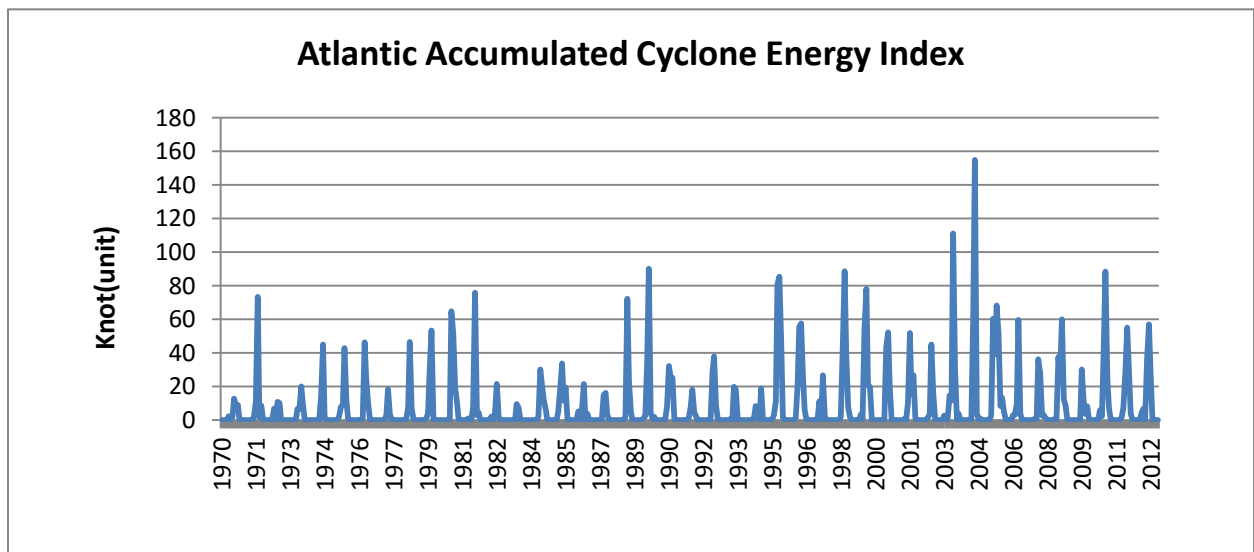


Figure 1. Atlantic Accumulated Cyclone Energy Index (AACE)

Note: We use the Atlantic ACE Index (AACE) since insured losses for natural catastrophes would still be concentrated in the US due not only to natural occurrence but also to higher penetration rates; while, the global value of the ACE Index is also adopted to test the robustness of our regression results.

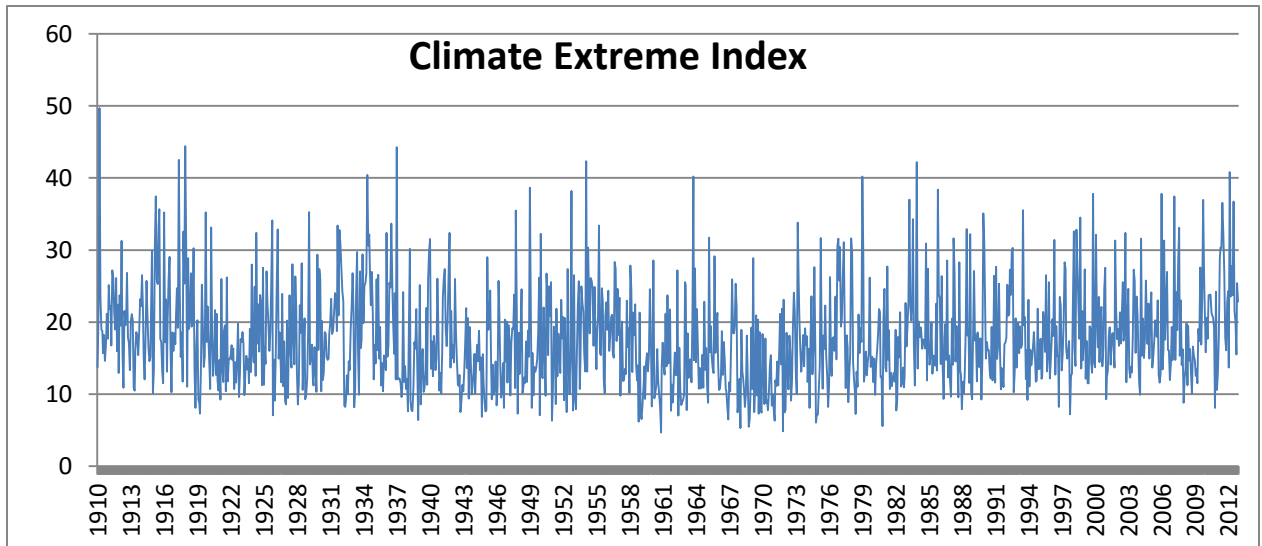


Figure 2. US Climate Extremes Index (CEI)

2.1.2 U.S. Climate Extremes Index

The U.S. Climate Extremes Index (herein CEI, 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 (<http://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 the extreme weather conditions in U.S, to the extent extreme weather in the US 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 US exposure.

2.2 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 losses³. 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, 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.⁴ We will also investigate the large general insurers ING and AIG who have property exposure⁵.

³ Government agencies will also provide financial support to private insurers.

⁴ Kunreuther and Michel (2007) found the price of catastrophe reinsurance in the U.S. rose significantly as a result of the 2004 and 2005 hurricane seasons.

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

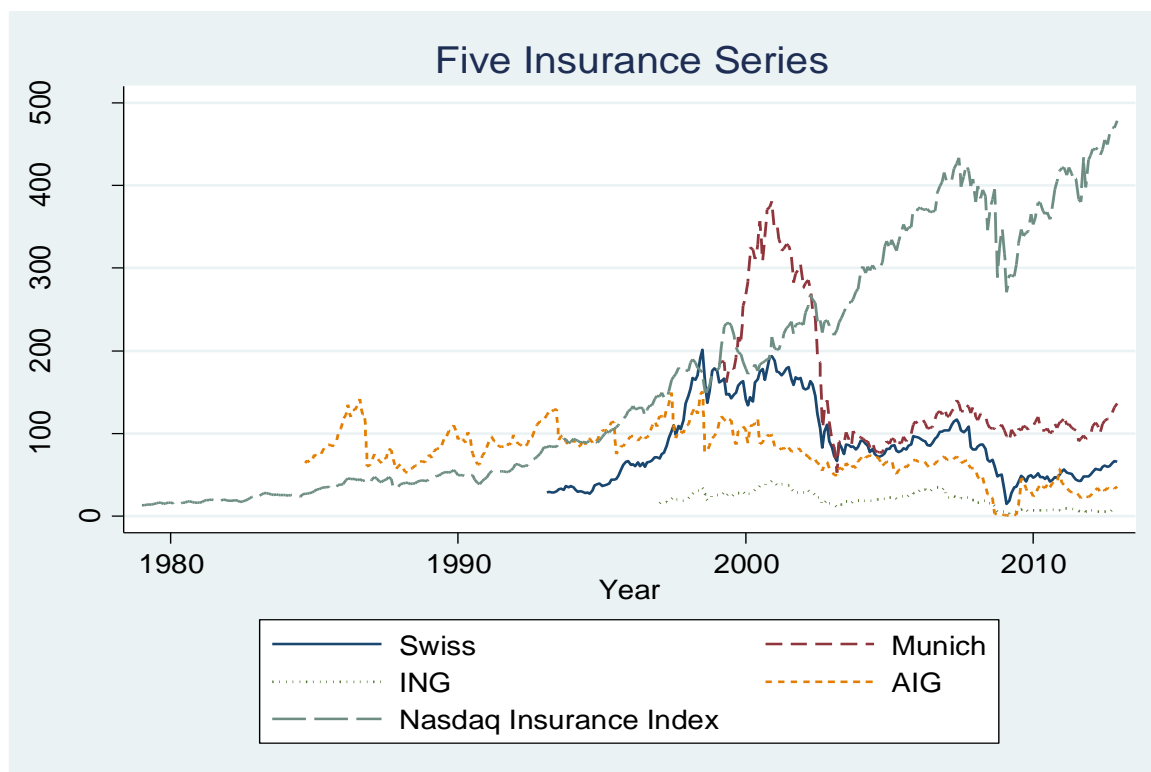


Figure 3. Trading Stock Prices for Five Insurance Series

Note: Munich Re, Swiss Re and ING are all measured in Euros; AIG is measured in Dollars; NASDAQ Insurance Index is rescaled by 10^{-1} .

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.⁶ 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

⁶ Detailed information of components for NASDAQ insurance index is available at <http://finance.yahoo.com/q/cp?s=^IXIS>

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 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 only traded on the NYSE, its 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.

3. Investigating the short-run relationship between climatic variables and insurance prices

3.1 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 stock market: an overall market factor, factors related to the firm size and book-to-market equity. The basic Fama-French model is following:

$$r - R_f = \alpha + \beta(R_{\text{MKT}} - R_f) + \beta_1\text{SMB} + \beta_2\text{HML}. \quad (1)$$

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 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 average return of two portfolios that have BE/ME (book to market ratio) high and average return of two portfolios that have BE/ME low.

To use a linear regression framework we need to ensure 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 both AACE and CEI are stationary process.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

⁷ We compute monthly rates of return for the insurance companies (r_t) using the formula $\text{Log}P_t - \text{Log}P_{t-1}$ (where P_t is the monthly closing share price at time t). For Nasdaq Insurance Index, the original data of monthly closing share price was chosen by taking 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.

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.

$$ER_t = \alpha + \beta(ER_{MKT})_t + \beta_1SMB_t + \beta_2HML_t + A_1(L)CEI_t + A_2(L)AACE_t + \text{seasonal dummies} + \varepsilon_t \quad (2)^9$$

where ER_t and $(ER_{MKT})_t$ represents 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; for AIG and NASDAQ insurance index, since both of them are traded on the NYSE, Fama-French factors for U.S are used for these two regressions. α is the constant term; seasonal dummies are included to account for seasonality in the climate indicators¹⁰; $A_1(L)$ and $A_2(L)$ denote respectively the lag operators for climate variables;¹¹ and ε_t is the residual.

⁹ Here $ER_t = r_t - (R_f)_t$; $(ER_{MKT})_t = (R_{MKT})_t - (R_f)_t$.

¹⁰ Sometimes 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 stock market, so we include the lag operators for the climate variables.

3.2 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.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:

$$\text{ER. swiss}_t = \underbrace{0.176}_{(0.10)} + \underbrace{0.52(\text{ER}_{\text{MKT}})_t}_{(0.11)} - \underbrace{0.19\text{SMB}_t}_{(0.06)} + \underbrace{0.16\text{HML}_t}_{(0.07)} + \text{seasonal dummies} + \varepsilon_t, \quad (3)$$

Here and in the following equations, the number in parentheses underneath the coefficient is the Newey-West standard error.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’ on the dependent variable denotes the excess rate of return.

¹² BIC is the Bayesian Information Criterion. BIC has been widely used for model identification in time series and linear regression. It guards against overfitting 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.

From equation (3), both the variation of AACE and CEI are not correlated with the excess return of Swiss Re respectively. 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.

ii) Munich Re

The final regression model for Munich Re is

$$\begin{aligned} \text{ER. munich}_t = & \underbrace{0.12}_{(0.14)} + \underbrace{0.08\text{CEI}_{t-8}}_{(0.04)} + \underbrace{0.003\text{AACE}_{t-9}}_{(0.002)} + \underbrace{0.41(\text{ER}_{\text{MKT}})_t}_{(0.14)} - \\ & \underbrace{0.28\text{SMB}_t}_{(0.10)} - \underbrace{0.02\text{HML}_t}_{(0.05)} + \text{seasonal dummies} + \varepsilon_t. \quad (4) \end{aligned}$$

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

$$\begin{aligned}
ER.ING_t = & \underbrace{-0.26}_{(0.10)} + \underbrace{0.09CEI_{t-2}}_{(0.04)} + \underbrace{0.005AACE_{t-4}}_{(0.003)} + \underbrace{0.64(ER_{MKT})_t}_{(0.09)} \\
& - \underbrace{0.10SMB_t}_{(0.05)} + \underbrace{0.17HML_t}_{(0.05)} + \text{seasonal dummies} + \varepsilon_t.
\end{aligned}
\tag{5}$$

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:

$$\begin{aligned}
ER.AIG_t = & \underbrace{0.006}_{(0.05)} + \underbrace{0.04CEI_{t-1}}_{(0.02)} + \underbrace{0.48(ER_{MKT})_t}_{(0.14)} + \underbrace{0.002SMB_t}_{(0.05)} + \\
& \underbrace{0.23HML_t}_{(0.13)} + \varepsilon_t.
\end{aligned}
\tag{6}$$

Only the first lagged index of CEI is positive and significant with p -value=0.057, without the effects of AACE. The seasonal dummies are dropped because all of them are insignificant; also, the coefficients of other independent variables are not affected by dropping seasonal dummies.

v) Insurance Index

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

$$\begin{aligned}
 \text{ER.insurance}_t = & -\underbrace{0.02}_{(0.07)} + \underbrace{0.07\text{CEI}_{t-1}}_{(0.04)} + \underbrace{0.07\text{CEI}_{t-2}}_{(0.04)} + \underbrace{0.08\text{CEI}_{t-3}}_{(0.04)} + \underbrace{0.09\text{CEI}_{t-9}}_{(0.04)} + \\
 & \underbrace{0.004\text{AACE}_{t-2}}_{(0.002)} + \underbrace{0.62(\text{ER}_{\text{MKT}})_t}_{(0.05)} + \underbrace{0.18\text{SMB}_t}_{(0.06)} + \underbrace{0.25\text{HML}_t}_{(0.07)} + \varepsilon_t.
 \end{aligned}$$

(7)

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 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 extreme weather events. Therefore, our results indicate that there is little evidence to suggest 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 allow reinsurers to plan for future trends in of 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.

3.3 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 US due not only to natural occurrence but also to higher penetration rates. But the insurance coverage of these big insurance companies in Asia and South America market has grown very quickly in recent years, so we also use the Global Accumulated Cyclone Energy index (GACE) as explanatory variable to test the consistency of our regression results, which is reported at table 3. The regression results are very similar to the case of using AACE. CEI is not correlated with the excess return to Swiss Re, but significantly and positively affects the excess return to other four insurance series. There is significant and positive marginal effect of GACE on

NASDAQ insurance index, but no relationship with Swiss Re, Munich Re, ING and AIG. 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 US insurance companies which have property exposure and business coverage along the east coast¹⁴. 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 other three insurance companies. The case of US insurance companies again supports our previous results that the insurance companies may not be adversely affected by the climate variations.

4. Conclusion

Financial losses associated with extreme weather activities have been increasing in past years. Insurance companies and others have expressed the 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 climate extreme

¹⁴ These five insurance companies include 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).

conditions, as measured by the CEI Index, increases 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 Nasdaq insurance index. In addition, using the Global Accumulated Cyclone Index as explanatory variable or including more U.S insurance firms into 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 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

ABI, “Adapting to Our Changing Climate: A Manifesto for Business, Government, and the Public”. Association of British Insurers, 2007.

Bell, Gerald D., Halpert, Michael S., Schnell, Russell C., Higgins, R. Wayne, Lawrimore, J., Kousky, Vernon E., Tinker, R., Thiaw, W., Chelliah, M. and Artusa, A., “Climate Assessment for 1999.” *Bulletin of the American Meteorological Society*, vol. 81, pp. 1328-1328, 2000.

Bengtsson, Lennart and Kevin Hodges, “Evaluating temperature trends in the tropical troposphere.” *Climate Dynamics* 2009, doi: 10.1007/s00382-009-0680-y.

- Böhme, H., “Insurance Company Is Making the Most of Climate Change” *Your Guide to Germany*, 2006. <http://www.dw-world.de/dw/article/0,2144,2242974,00.html>
- Charpentier, A., “Insurability of Climate Risks.” *The Geneva Papers*, vol. 33, pp. 91-109, 2008.
- Chen, L. and Zhang L., “A Better Three Factor Model That Explains More Anomalies”, *The Journal of Finance*, vol. 2, pp. 563-595, 2010.
- Chief Risk Officers (CRO), “CRO briefing” *CRO position paper of leading primary insurers and reinsurers on climate change and the hurricane risk in the North Atlantic*, 2006.
http://www.munichre.com/app_resources/pdf/ts/geo_risks/crobriefing_en.pdf
- Choi, O. and Fisher, A., “The Impacts of Socioeconomic Development and Climate Change on Severe Weather Catastrophe Losses: Mid-Atlantic Region (MAR) and the U.S.” *Climatic Change*, vol. 58, pp. 149-170, 2003.
- Clemo, K. (2008). “Preparing for Climate Change: Insurance and Small Business”, *The Geneva Papers*, vol. 33, pp. 110–116, 2008.
- Crichton, D., “Role of Insurance in Reducing Flood Risk”, *The Geneva Papers*, vol 33, pp. 117–132, 2008.
- Dlugolecki, Andrew, “A Changing Climate for Insurance – A Summary Report for Chief Executives and Policy Makers.” *Association of British Insurers*, 2004.
http://www.abi.org.uk/Display/File/364/SP_Climate_Change5.pdf
- Dlugolecki, A., “Climate Change and the Insurance Sector.” *The Geneva Papers*, vol. 33, pp. 71–90, 2008.
- Durack, Paul J., Wijffels, Susan E. and Matear, Richard J., “Ocean Salinities Reveal Strong Global Water Cycle Intensification During 1950 to 2000”, *Science*, Vol. 336 , no. 6080, pp. 455-458, 2012

Fama, Eugene F. and French, Kenneth R., “common risk factors in the returns on stocks and bonds.”, *Journal of Financial Economics*, vol 33, pp. 3-56, 1993.

Fama, Eugene F., and French, Kenneth R., “Multifactor explanation of asset pricing anomalies”, *Journal of Finance* 51, pp. 55–84,1996.

Enders, Walter, “Applied Econometric Time Series”, Hamilton Printing, 2004.

Engel, R. F. and C. W. Granger, “Co-integration and error correction: Representation, estimation, and testing.” *Econometrica*, vol. 55, pp. 251–76, 1987.

Environmental Science & Technology (EST), “The insurance industry prepares for climate change” *Interview with Evan Mills*, 2006.

http://pubs.acs.org/subscribe/journals/esthagw/2006/apr/business/pt_insurance.html

Folland, Christopher and D.E. Parker, “Correction of instrumental biases in historical sea surface temperature data.” *Quart. J. Roy. Meteor.Soc.* vol. 121, pp. 319–367, 1995.

Hall, B.H., Cummins, C., “TSP 5.0 User’s Guide.” *TSP international*, 2006

<http://www.tspintl.com/products/TSP50UG.pdf>

Heij, C., et al, “Econometric Methods with Applications in Business and Economics”. New York: Oxford University Press, pp. 286-362, 2004.

ING, “Share Performance.” *Investor Relations*, 2008.

<http://www.ing.com/group/stockticker.jsp?menopt=ivr|shf|stc&menopt=ivr|shf|stc>

Insurance Journal, “New Report Warns of Rising Threat to Industry from Climate Change”, *Insurance Journal - National News*, 2005.

Insurance Journal, “Lloyd’s Report Says Climate Change Should Be a Constant Consideration” , *Insurance Journal - International News*, 2014.

Hartmann, D.L., A.M.G. Klein Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling, A. Kaplan, B.J. Soden,

P.W. Thorne, M. Wild and P.M. Zhai, 2013: Observations: Atmosphere and Surface. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Krause, S., “Better Off without the Euro? Evaluating Monetary Policy and Macroeconomic Performance for Denmark, Sweden and the U.K.” 2 Aug, 2008.
<http://userwww.service.emory.edu/~skrause/pdf/whatif01.pdf>

Knutson, Thomas R., Sirutis, Joseph J., Garner, Stephen T., Vecchi, Gabriel A. and Held, Isaac M., “Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions”, *Nature Geoscience*, Vol. 1, No. 6, pp. 359-364, 2008.

Kunreuther, H.C., Michel-Kerjan, E.O., “Climate Change, Insurability of Large-Scale Disasters, And the Emerging Liability Challenge.” NBER Working Paper No.12821, 2007.

Landsea, C. W., “Hurricanes and global warming.” *Nature (London)*, 438, 7071, E11–13, 2005.

Lutkepohl, H., *New introduction to multiple time series analysis*. New York: Springer, 2005.

Mac-Donald-Smity, A., “Climate Change to Boost Insured Losses, Allianz Says,” *Blomberg*, September 18, 2007.

Maddala, G.S., *Introduction to Econometrics* (2nd edition). New York: Macmillan Publishing Company, 1992.

Maue, R. N., “Northern Hemisphere Tropical Cyclone Activity.” *Geophysical Research Letters* 36, L05805, doi:10.1029/2008GL035946, 2009.

Maue, R. N., “Recent historically low global tropical cyclone activity” *Geophysical Research Letters* 38, L14803, 6 PP., doi:10.1029/2011GL047711, 2011.

Maynard, T., “Climate Change: Impacts on Insurers and How They Can Help With Adaptation and Mitigation.” *The Geneva Papers*, vol. 33, pp. 140–146, 2008.

Mears, C. A., M. C. Schabel, and F. J. Wentz. 2003. A reanalysis of the MSU channel 2 tropospheric temperature record. *J. Climate* 16, no. 22: 3650-3664.

Michel-Kerjan, E. and Morlaye, F., “Extreme Events, Global Warming, and Insurance-Linked Securities: How to Trigger the “Tipping Point”, *The Geneva Papers*, vol. 33, pp. 153–176, 2008.

Michael, W., Land, P. and Jonathan, I., “The social foundations of poor economic growth in resource-rich countries”, *Resource Abundance and Economic Development*, Oxford University Press, 1999.

Mills, E., "Responding to Climate Change – The Insurance Industry Perspective." In *Climate Action*, Sustainable Development International (in partnership with the United Nations Environment Programme), December, pp. 100-103, 2007.

Mills, E., “Evan Mills, Ph.D.” *Environmental Energy Technologies Division*, 2008.
<http://eetd.lbl.gov/EMills/>

Munich Re Group, “Share price and chart service.” *Investory Relations*, 2009.
http://www.munichre.com/en/ir/shares/chart_service/performance_data.aspx

Nau, R.F., “Stationarity and differencing.” & “Testing the assumptions of linear regression.” *DECISION 411 Forecasting*, 2008.
<http://www.duke.edu/~rnau/411diff.htm>
<http://www.duke.edu/~rnau/testing.htm>

Pielke, Jr. R.A., Gratz, J., Landsea, C.W., Collins, D., Saunders, M.A., Musulin, R., “Normalized Hurrican Damage in the United States: 1900-2005.” *Natural Hazards Review*, vol.9, No.1, Feb, 2008.

Pielke Jr., R.A., Sarewitz, D, “Bringing Society Back into the Climate Debate.” *Population and Environment*, vol.26, No.3, Jan. 2005.

Randall, R.M.; Herman, B.M. "Using limited time period trends as a means to determine attribution of discrepancies in microwave sounding unit-derived tropospheric temperature time series." *J. Geophys. Res.* 2008, doi: 10.1029/2007/JD008864.

Rayner, N.A., P.Brohan, D.E.Parker, C.K.Folland, J.J.Kennedy, M.Vanicek, T.Ansell and S.F.B.Tett, Improved analyses of changes and uncertainties in sea surface temperature measured *in situ* since the mid-nineteenth century: the HadSST2 data set. *Journal of Climate*, vol. 19, no. 3, pp. 446-469, 2006.

Shin, A., "Global Warming Ate My Insurance Policy." *The Checkout. The Washington Post*. 22, December, 2006.

http://blog.washingtonpost.com/thecheckout/2006/12/allstate_cuts_off_coastal_resi.html

Spencer, R.W., Christy, J.R., Grody, N.C., "Global Atmospheric Temperature Monitoring with Satellite Microwave Measurements: Method and Results 1979-84." *Journal of Climate*, vol. 3, Issue 10, pp.1111-1128, 1990.

Swiss Re, "The effects of climate change: Storm damage in Europe on the rise" *Focus Report*, 2006.

http://www.swissre.com/resources/0e9e8a80455c7a86b1e4bb80a45d76a0-Publ06_Klimaveraenderung_en.pdf

SWX Swiss Exchange Europe, "virt-x changes its name to SWX Europe." *Media Release*. 3 Mar 2008.

<http://www.swxeurope.com>

Tucker, M., "Climate change and the insurance industry: the cost of increased risk and the impetus for action." *Ecological Economics*, vol. 22, pp. 85-96, 1997.

Vecchi, Gabriel A., Swanson, Kyle L. and Soden, Brian J., "Whither hurricane activity?", *Science* 31, Vol. 322. No. 5902, pp. 687-689, 2008.

Wahana Tata Insurance (WTI), “Swiss Re Beats Munich Re in '08, Still at Discount.”
News-General, 2008.

http://www.aswata.co.id/index.php?op=article_view&id_news=507

Ward, Robert E.T., Herweijer, C., Patmore, N. and Muir-Wood, R., “The Role of Insurers in Promoting Adaptation to the Impacts of Climate Change”, *The Geneva Papers*, vol. 33, pp. 133–139, 2008.1

Wharton, “Managing Large-Scale Risks in a New Era of Catastrophes: Insuring, Mitigating and Financing Recovery from Natural Disasters in the United States”, An Extreme Events Project of the Wharton Risk Management and Decision Processes Center in conjunction with Georgia State University and the Insurance Information Institute, 2008.

White House, “National Climate Assessment report”, 2014.

Woodruff, S.D., H.F. Diaz, E.C. Kent, R.W. Reynolds, and S.J. Worley (2008) “The evolving SST record from ICOADS.” In *Climate Variability and Extremes during the Past 100 Years* (S. Brönnimann, J. Luterbacher, T. Ewen, H.F. Diaz, R.S. Stolarski, and U. Neu, Eds.), *Advances in Global Change Research*, Vol. 33, Springer, 65-83 (DOI:10.1007/978-1-4020-6766-2_4).

Table 1: Summary Statistics

Variable Code	Variable Name	Units	Observations	Mean	Std. Dev	Min	Max
CEI	Climate Extremes Index	%	408	18.61	6.73	5.56	42.20
ACE	Accumulated Cyclone Energy	10^4kt^2	408	63.09	45.74	0.00	266.39
AACE	Atlantic ACE	10^4kt^2	408	8.86	19.57	0.00	155.01
Swiss	Swiss Re share price	Euro	239	88.66	47.05	14.53	201.55
Munich	Munich Re share price	Euro	167	150.38	82.69	52.50	381.06
ING	ING share price	Euro	192	19.88	10.14	2.82	42.54
AIG	AIG share price	Dollars	340	72.83	30.32	0.42	150.82
Index	NASDAQ Index share price		408	1684.19	1425.58	128.74	4785.14
ALL	The Allstate Corporation	Dollars	235	41.81	15.81	16.83	96.25
ACGL	Arch Capital Group Ltd.	Dollars	208	40.59	22.35	12.62	104.00
AGII	Argo Group International Holdings, Ltd.	Dollars	314	31.93	13.72	8.55	93.00
BWINA	Baldwin & Lyons Inc.	Dollars	319	22.46	5.08	12.00	46.00
FNHC	Federated National Holding Company	Dollars	170	8.95	6.22	1.35	28.18
ER _{MKT}	Rate of US market excess return		408	0.60	4.57	-23.24	12.46
SMB	excess returns of small caps over big caps (US)		408	0.18	3.08	-16.39	22.00
HML	excess returns of value stocks over growth stocks (US)		408	0.32	3.06	-12.60	13.84
EER _{MKT}	Rate of Europe market excess return		270	0.47	5.14	-22.14	13.78

ESMB	excess returns of small caps over big caps (Europe)		270	-0.08	2.31	-6.94	9.31
EHML	excess returns of value stocks over growth stocks (Europe)		270	0.40	2.40	-9.57	10.96

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.

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)

	Swiss Re	Munich Re	ING	AIG	Index
CEI		0.078* (7)	0.092* (2)	0.042*	0.073(1) 0.071 (2) 0.076*(3) 0.094*(9)
AACE		0.003(9)	0.005(4)		0.004 (2)
ER _{MKT}	0.525**	0.411**	0.638**	0.480**	0.618**
SMB	- 0.194**	- 0.278**	- 0.104*	0.002	0.177**
HML	0.155*	- 0.016	0.173**	0.235	0.255**
CONS	0.176	0.115	- 0.263**	0.006	-0.024
R ²	0.43	0.28	0.61	0.21	0.43
AIC	550	425	374	887	915
BIC	574	453	403	906	951
Obs	238	166	191	339	399
Month	1993.02	1999.02	1997.01	1984.09	1979.01

Marginal effects

CEI	0.078*	0.092*	0.042*	0.314**
AACE	0.003	0.005		0.004

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 number in small bracket in the upper table indicates 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.

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)

	Swiss Re	Munich Re	ING	AIG	Index
CEI		0.078* (7)	0.112** (2)	0.042*	0.071 (1) 0.073 (2) 0.078* (3) 0.099* (9)
ACE	0.082 (2) - 0.052 (6)		0.138 (4) - 0.092 (8) - 0.089 (10)		0.088* (2) 0.094 (7)
ER _{MKT}	0.520**	0.410**	0.642**	0.480**	0.619**
SMB	- 0.211**	- 0.275**	- 0.109*	0.002	0.177**
HML	0.154*	- 0.015	0.160**	0.235	0.251**
CONS	0.010	0.118	- 0.249*	0.006	0.013
R ²	0.42	0.28	0.61	0.21	0.43
AIC	552	424	373	887	920
BIC	573	449	409	906	971
Obs	238	166	191	339	399
Month	1993.02	1999.02	1997.01	1984.09	1979.01

Marginal effects

CEI		0.078*	0.112**	0.042*	0.321**
ACE	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 number in small bracket in the upper table indicates 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.

Table 4 OLS estimation of the impact of climate variability on the monthly excess return of share prices of U.S. insurance companies (Atlantic Accumulated Cyclone Energy index as independent variable)

	ALL	ACGL	AGII	BWINA	FNHC
CEI	0.099** 0.148**	0.108 (3)	0.072 (3)	0.111(2) 0.095(9) -0.096* (10) 0.095* (11)	0.122*(2) 0.103*(4) -0.123(10)
AACE	0.006*		-0.003* (6) 0.005**(12)	0.006	0.008*(7) -0.008*(8)
ER _{MKT}	0.542**	0.146**	0.356**	0.204**	0.181**
SMB	- 0.043	0.194**	0.129*	0.080*	0.142
HML	0.388**	0.186**	0.117*	0.025	0.037
CONS	0.111	0.179*	- 0.097	-0.158*	-0.005
R ²	0.39	0.08	0.15	0.08	0.10
AIC	560	576	846	889	471
BIC	594	603	883	934	499
Obs	234	207	313	318	169
Month	1993.06	1995.09	1986.11	1986.06	1998.11

Marginal effects

CEI	0.247**	0.108	0.072	0.205	0.102
AACE	0.006*		0.002	0.006	0.000

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 number in small bracket in the upper table indicates 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.

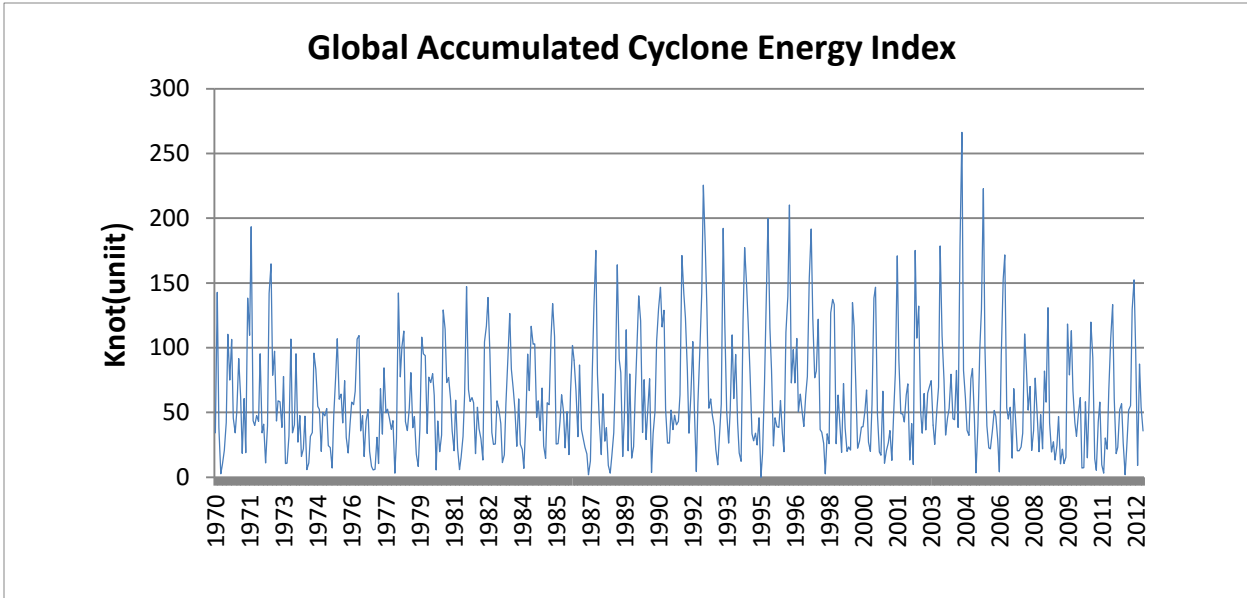


Figure 4. Global Accumulated Cyclone Energy Index

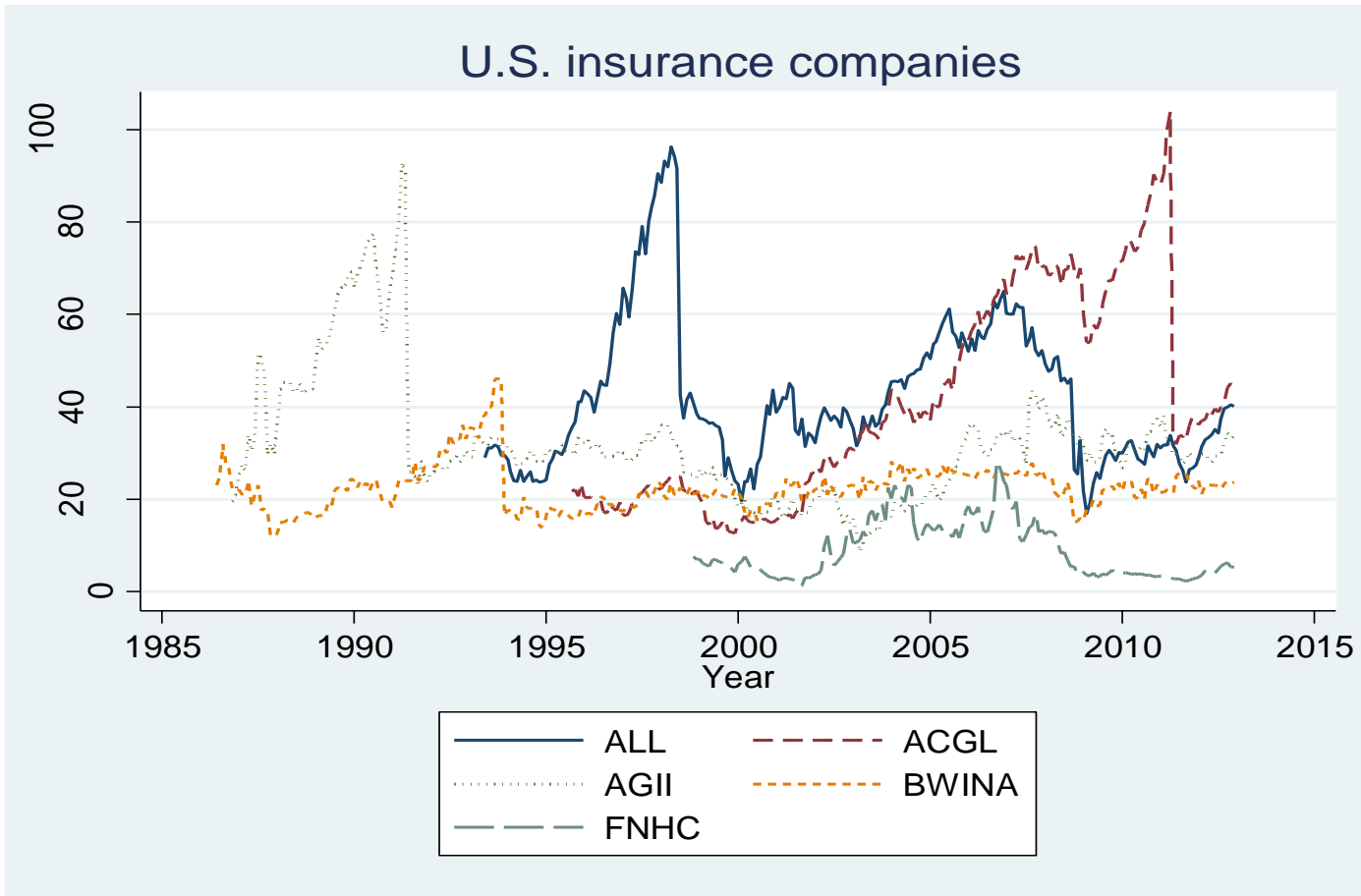


Figure 5. Trading Stock Prices for Five Insurance Series

Note: All the share prices of five U.S. insurance companies are measured in Dollars and traded in NASDAQ.