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The Impact of Natural Disasters on Stock Markets: Evidence from Japan and the US

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This paper investigates the impact of natural disasters on the insurance sector as well as on the composite stock market in Japan and the US. GARCH models are employed to capture both wealth and risk effects of natural disasters. There are no wealth effects in the US and Japan composite stock markets, indicating that these markets can well diversify away the impact of natural disasters on stock return, but there are significant wealth effects in the US and Japan insurance sectors. While US investors in the insurance sector lose, those in Japan gain. All markets except the composite stock market in Japan face risk effects of natural disasters.
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INTRODUCTION

Japan and the United States (US) are among the countries that have suffered extensively from natural disasters, especially earthquakes, tsunamis, and volcanoes, due to their geographic location. Japan lies right at the junction of the Pacific plate and the Eurasian plate while the US is adjacent to the Pacific plate. The movement of these plates often causes earthquakes and volcanoes, many of which are associated with tsunamis. A 9.0-magnitude earthquake struck the Pacific coastal areas of Japan on 11 March 2011, churning up a devastating tsunami. It was the most powerful quake on record to hit Japan.

As of 25 April 2011, the death toll reached 14,358 while 11,889 were listed as missing.[1] The nuclear crisis that resulted from the earthquake made the situation even worse. The financial loss is expected to reach 309 billion US dollars, the largest loss from a natural disaster in the world.[2] The US also suffered from earthquakes, tsunamis, and hurricanes. For example, according to the National Weather Service and the Insurance Information Institute, damage of more than $501.1 billion and a death toll of 22,240 resulted from the top 10 US natural disasters during 1980–2010.[3]

Another reason that makes Japan and the US of interest is that the two countries are among the largest economies in the world. The Japanese Nikkei 225 and the Standard and Poor's 500 are broadly cited stock indices, and the Japanese Yen and the US dollar are the most frequently used currencies in international trade as well as in financial markets. If the frequent natural disasters have a significant impact on the domestic financial markets, such as on the insurance companies and the composite stock index, there might be contagious effect on other financial markets around the world. Researchers have shown that natural disasters have an impact on the insurance industry (Yamori and Kobayashi, 2002; Shelor *et al.*, 1992). Also, there were fluctuations in the Nikkei 225 and the Standard and Poor's 500 stock indexes after the 11 March earthquake and tsunami in 2011. Since the composite stock index represents a well-diversified portfolio, it is a better measure of the overall performance of the financial market than a single asset, such as crude oil or gold, which usually shows higher volatility in return due to lack of diversification. According to the Capital Asset Pricing Model, any risk that could potentially be reduced by diversification should not yield extra return beyond the market return. What really matters is the systematic risk that cannot be diversified away (Ross *et al.*, 2010). In this case, if there are any changes in the stock market return that are due to natural disasters, special attention to the impact of natural disasters will be necessary since these impacts could not be effectively absorbed by the market and may lead to significant wealth losses when they happen again in the future. However, some studies summarized in the review section have reported some gains in stock returns in the insurance sector due to natural disasters and they explained this based on the so-called 'gaining from loss hypothesis', which suggests that investors tend to demand more insurance coverage during times of natural disasters to maximize their protection and hence insurance sector profits increase yielding higher stock returns in this sector.

[1] Source: http://news.xinhuanet.com/english2010/world/2011-04/25/c_13845359.html.
[2] Source: http://liberalsprinkles.blogspot.com/2011/03/facts-japan-earthquake-tsunami-nuclear.html.
[3] Source: http://www.bankrate.com/finance/insurance/top-10-costliest-natural-disasters-1.aspx.

The objective of this paper is to investigate whether there is any undiversifiable impact of natural disasters on the insurance sector stock market return as well as on the composite stock market return in Japan and the US. Such impact is referred to as the wealth effect. This paper also examines the risk effect, which is the impact of natural disasters on stock market volatility.

The paper is divided into seven sections. Following this introduction, the next section reviews the existing literature. The subsequent section discusses the contribution of this paper. The methodology employed in this study is explained in the latter section. The following section describes data and provides the descriptive statistics. The penultimate section discusses the estimation results and findings. Finally, conclusion and implications are provided in the final section.

LITERATURE REVIEW

Although several studies examine the impact of natural disasters from an economic perspective, most of them focus on the property liability insurance industry. However, there are no consistent conclusion on whether the stock prices of insurance companies drop or rise after severe natural disasters.

Yamori and Kobayashi (2002) investigate the impact of the Japanese Hanshin–Awaji earthquake, which hit the Tokyo metropolitan area in 1995, on the stock prices of Japanese insurance firms. This earthquake cost the insurance companies approximately 77 billion yen, the largest payment since the Japanese earthquake insurance system was established. Their study is the first to test the gaining from loss hypothesis outside the US. They use an event study methodology based on Ordinary Least Squares (OLS), and, by creating a portfolio of 13 insurance companies, they calculate the daily abnormal returns of the portfolio from day 0 to day 9 after the earthquake happens. They get a significantly negative abnormal return on day 0, which is the day the earthquake. The results are quite consistent based on pre- and post-period estimations. They reject the hypothesis that insurance companies can benefit from increased demand for their products after a natural disaster, contrary to some studies for the US insurance sector. The authors do not provide possible explanations of such difference. This study employs a small number of companies included in the portfolio, possibly leading to biased estimates.

Lamb (1995) also reports evidence of a negative stock price response on property liability insurers after Hurricane Andrew hit Florida and Louisiana in 1992. The sample consists of 37 publicly held property liability insurance companies. Daily stock returns are used to calculate abnormal returns from 10 days before the hurricane to 30 days after it. The results reveal negative stock price responses of property liability insurance companies that are exposed to the losses. However, no significant stock price response is observed for insurance companies without loss exposure in the two states. The estimation of stock betas is only based on the pre-event period without testing stability of betas before and after the hurricane. Stock betas are very likely to change due to volatility change caused by the natural disaster.

Shelor *et al.* (1992) examine the ‘gaining from loss’ hypothesis based on the 1989 California earthquake in the US and reach different conclusions. Their study also adopts an event study methodology, but uses Generalized Least Squares and Non-generalized Least Squares for estimation. They create two portfolios one with property liability insurers and the other with multiple product insurers, with sample sizes of 47 and 32, respectively. Daily stock returns are used to calculate abnormal returns from day 0 to day 15 after the earthquake. They test risk stability for the pre-event period and post-event period and do not observe any change in stock betas. Their result supports the gaining from loss hypothesis, because they find evidence of significant increase in stock value of both portfolios after the earthquake. From a cross-sectional analysis, they also conclude that stock value of California insurance companies had a smaller increase than that of companies that did not write insurance in California because the positive effect of California insurance companies is partially offset by the loss payments.

Worthington and Valadkhani (2004) examine the impact of natural disasters on the Australian stock market by using intervention analysis based on an Autoregressive Moving Average (ARMA) model. The data employed are daily stock market returns covering the period of 31 December 1982 to 1 January 2002. They conclude that natural disasters, especially cyclones and bushfires, have an impact on Australian stock market and the net effects can be positive and/or negative depending on the adjustment in the days that follow the disasters.

Another study by Worthington (2008) adopts the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) and the GARCH-in-the-mean model based on the Australian stock market. The data are daily stock market returns covering the period of 1 January 1980 to 30 June 2003. The results indicate that there is no significant impact of natural disasters on Australian stock market returns. The shocks do not create systematic risk in the market, and they are diversified away at the market level.

CONTRIBUTION

First of all, this paper contributes to the literature by extending the topic geographically to Japan and the US, and by investigating the impact of disasters on both the insurance sector and the composite stock market. Second, compared with previous studies, most of which use OLS, this study employs the GARCH model, which is the same methodology that Worthington (2008) uses for Australian stock market. However, this paper improves the analysis by including necessary control variables that Worthington (2008) omits, for example, foreign stock returns, the exchange rate, and the interest rate, etc. Moreover, this study examines the impact of natural disasters not only in the mean equation, but also in the conditional variance equation, which is used as a proxy for risk.

METHODOLOGY

GARCH models are employed in this study. First of all, GARCH models allow time-varying volatility while OLS assumes constant volatility. As shown in Figure 1, it is clear that GARCH model is a better model than OLS because the amplitude of the series varies over time. Also, compared with the ARCH model, GARCH model captures the impact of all the past shocks and it is more parsimonious because it uses past volatility rather than all lags of shocks. TARCH and E-GARCH models both take into account the asymmetric term, which measures the different impact of bad news and good news on volatility (Enders, 2010). In this study, the E-GARCH (1, 1) model is selected since it has the highest maximum log-likelihood value.[4]

The model of stock market returns is described below:

Mean (conditional return) equation capturing wealth effects:

Japan:

$$\begin{aligned}\mathrm{Re}t\_jp_t =& \alpha_0 + \alpha_1 \mathrm{Re}t\_us_{t-1} + \alpha_2 Chg\_IR\_jp_{t-1} + \alpha_3 \mathrm{Re}t\_EXR_{t-1} \\ &+ \sum_{k=0}^{5} \alpha_{4+k} ND\_jp_{t-k} + \varepsilon_t\end{aligned} \tag{1}$$

US:

$$\begin{aligned}\mathrm{Re}t\_us_t =& \alpha_0 + \alpha_1 \mathrm{Re}t\_jp_t + \alpha_2 Chg\_IR\_us_{t-1} + \alpha_3 \mathrm{Re}t\_EXR_{t-1} \\ &+ \sum_{k=0}^{5} \alpha_{4+k} ND\_us_{t-k} + \varepsilon_t\end{aligned} \tag{2}$$

[4] Baklavaci *et al.* (2011), Chen *et al.* (2010) and Janabi *et al.* (2010) employ similar types of GARCH models.

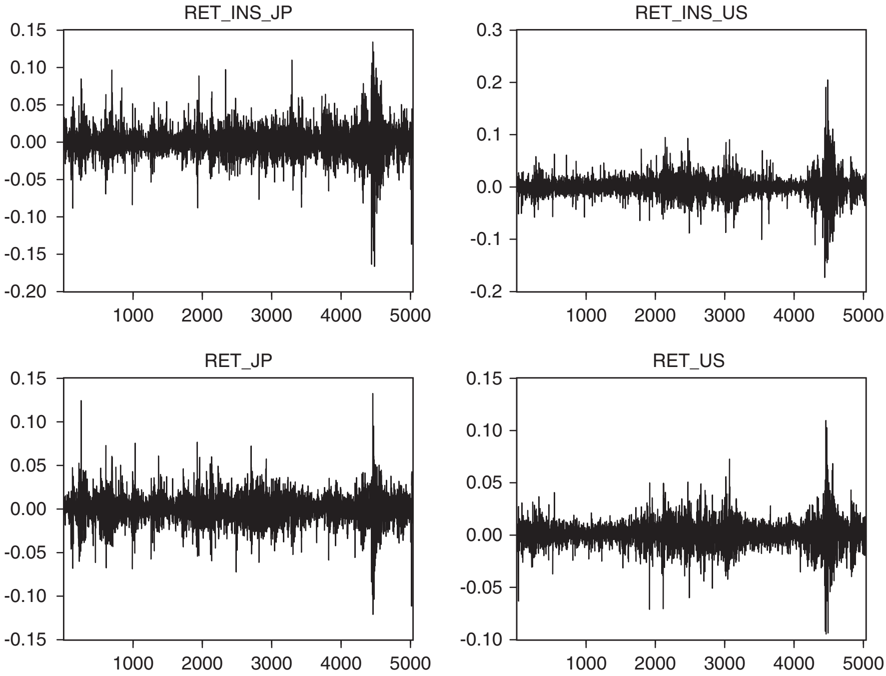

Figure 1: Plots of the stock return series

The dependent variables (Ret_US and Ret_Jp) are Japan and US (insurance sector and composite) stock returns. The stock market return of the foreign country, change in interest rate in the corresponding local market (Chg_IR), and the US Dollar-Japanese yen exchange rate return (Ret_EXR) are used as independent variables. Since major stock markets around the world affect each other, and big events have an impact on worldwide stock markets simultaneously, the performance of the US stock market should be highly correlated with the performance of the Japanese stock market. Also, changes in the interest rate may influence the local stock market. Appreciation and depreciation of the domestic currency may also bring about some changes in stock returns. Also, because the stock market index, the interest rate, and the exchange rate are financial market variables and may be affected simultaneously by domestic or global events, they are likely endogenous. Therefore, to avoid this problem, lag 1 terms of change in interest rate and return on exchange rate are used as control variables.

Current and five lags of natural disasters are included in the mean equation to capture their immediate and dynamic wealth effects on stock returns, respectively. Natural disasters include four different categories, namely, earthquakes, tsunamis, volcano eruptions and tropical cyclones, and each enters into the regressions separately as (0,1) dummy variables where 1 indicates that a natural disaster takes place at a given date.

The model of the conditional volatility of stock market returns is described below:

Conditional variance equation measuring risk effects:

Japan:

$$\ln(h_t) = \beta_0 + \beta_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \beta_2 \left(\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta_3 \ln(h_{t-1}) + \sum_{k=0}^{5} \beta_{4+k} ND\_jp_{t-k} \quad (3)$$

US:

$$\ln(h_t) = \beta_0 + \beta_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \beta_2 \left(\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta_3 \ln(h_{t-1}) + \sum_{k=0}^{5} \beta_{4+k} ND\_us_{t-k} \quad (4)$$

In the conditional variance equations, β_0 captures the constant or unconditional variance, while β_1 measures the impact of last period's shock on the conditional variance of returns and β_2 is the coefficient of the asymmetric term, capturing whether the impact of the shock is negative or positive. β_3 represents the lagged volatility capturing persistency in the conditional volatility of returns. To observe the impact of natural disasters on the conditional volatility (ie, a measure of risk) of insurance and composite stock markets, current and five lags of dummy variables of natural disasters are also added in the conditional variance equations.

DATA AND DESCRIPTIVE STATISTICS

We employ a financial data set and a natural disaster data set in this study. All financial data series are obtained from the Global financial data website.[5]

Data series employed in the insurance sector model include the following:

(1) Japan TOPIX Insurance Index
(2) S&P 500 Insurance Composite
(3) 10-year bond yield in Japan
(4) 10-year bond yield in US
(5) US Dollar-Japanese Yen exchange rate

[5] https://www.globalfinancialdata.com.

Data series employed in the composite stock market model contain the following:

(1) Nikkei 225 Stock Average
(2) S&P 500 Composite Price Index
(3) 10-year bond yield in Japan
(4) 10-year bond yield in US
(5) US Dollar-Japanese Yen exchange rate

All data are daily over the period from 11 September 1989 to 8 April 2011.

All stock returns are computed using the logarithm difference of the share indices. Figure 1 presents the plots of stock return series. Stock returns show similar patterns in the two countries. However, Japanese stock returns are more volatile than stock returns in the US. Also, Phillips-Perron tests unit root tests (not reported) were conducted to make sure that all series are stationary.

The second data set is the natural disaster data set. The National Geophysical Data Center provides data of several kinds of natural disasters – earthquake, tsunami, and volcano eruptions around the world. Information available is the time, location, and intensity.[6] The JAXA/EORC Tropical Cyclone Database is used to manually identify tropical cyclones that possibly impact Japan or the US, since tropical cyclones usually last for several days and this database does not provide specific date when a tropical cyclone hit a country.[7] We use the date when a tropical cyclone is closest to a country and match it with the stock market and other financial control variables. We examined tropical cyclones in the North Western Pacific for Japan and those in the North Eastern Pacific and North Atlantic for the US.

Four individual natural disaster (MD) dummy variables are employed to represent each natural disaster event separately in estimations based on the date it happened. Since it is likely that natural disasters may happen on weekend or holidays, when stock markets do not open, the dates of natural disasters are matched with the most recent trading day after the disaster. For example, if an earthquake occurs on Saturday, the performance of stock market next Monday is observed. There are totally 120 Japanese aggregate natural disaster events during 11 September 1989 to 8 April 2011, among which 61 are earthquakes, 36 are tsunamis, 4 are volcano eruptions, and 55 are tropical cyclones. Among these natural disasters, 36 earthquakes are associated with tsunamis. There are totally 100 US aggregate natural disaster events during 11 September 1989 to 8 April 2011, among which 39 are

[6] http://www.ngdc.noaa.gov/hazard/hazards.shtml.
[7] http://sharaku.eorc.jaxa.jp/TYP_DB/index_e.shtml.

Table 1: Descriptive statistics of stock returns

	Insurance sector stock return		Composite stock return	
	Japan	US	Japan	US
Mean	−0.000197	0.000187	−0.000246	0.000260
Maximum	0.133957	0.215313	0.132346	0.124042
Minimum	−0.166361	−0.142109	−0.121110	−0.094695
Std. Dev.	0.019246	0.019393	0.015947	0.012130
Skewness	−0.068378	0.045142	−0.136468	−0.055774
Kurtosis	9.554346	13.67934	8.588657	12.75274
Jarque-Bera	9132.858	24237.00	6652.860	20214.80
Probability	0.000000	0.000000	0.000000	0.000000
Observations	5,100	5,100	5,100	5,100

earthquakes, 15 are tsunamis, 4 are volcano eruptions, and 51 are tropical cyclones. Among these natural disasters, eight earthquakes are associated with tsunamis, and one tsunami is associated with volcano eruption. There is no overlap between tropical cyclones and other types of natural disasters in both Japan and the US.

Descriptive statistics of insurance sector and composite stock market returns are shown in Table 1. During the sample period, US stock returns in both the insurance sector and the composite market are positive and higher than those in Japan which are negative. Despite differences in returns, the standard deviations of returns in both countries are similar in the insurance sector, but the standard deviation of the US composite stock returns is smaller than that of Japan indicating that the Japanese insurance sector had a higher volatility during the sample period. This is also reflected in the differences in maximum and minimum returns in each sector. Skewness and kurtosis figures indicate that stock returns are not normally distributed and this is further supported by the Jarque-Bera tests, which reject the normality hypothesis in all cases.

ESTIMATIONS AND FINDINGS

Before we report our empirical findings, we first discuss a problem of time zone adjustment for the Japanese models. Hamao *et al.* (1990) summarize trading hours of different stock markets when they investigate the spillover effects across these markets. It reveals that there is no overlapping trading time between the two markets. Since an international date line divides the two stock markets so that Japan is one day ahead of the US, the performance of the US stock market becomes overnight news to the Japanese stock market.

Therefore, there needs some data pretreatment of the Japan TOPIX Insurance Index, S&P 500 Insurance Composite, Nikkei 225 Stock Average and S&P 500 Composite Price Index. Japan TOPIX Insurance Index at time t is matched with S&P 500 Insurance Composite at time $(t-1)$. The Nikkei 225 Stock Average at time t is matched with the S&P 500 index at time $(t-1)$. Specially, Monday in Japan is matched with Friday in the US. Although there were six trading days per week in Japan before 1990, these observations are deleted in order to be consistent with five trading days per week in the US. Meanwhile, there is some inconsistency regarding holidays in the two countries; these observations are also deleted when data are missing for either stock market due to holidays. Finally, stock returns are calculated after the data adjustment. In contrast, for the US model, the performance of the Japanese stock market at time t is the overnight news to the US stock market at time t; therefore, the S&P 500 Insurance Composite and S&P index at time t are matched with Japan TOPIX Insurance Index and the Nikkei 225 index at time t.

Table 2 presents the estimation results of both wealth and risk effects of natural disasters. Panel A reports the wealth effects while Panel B shows the risk effects. Panel C provides some diagnostic tests.

Table 2: Natural disasters and stock returns

Variable		US composite	US insurance	Japan composite	Japan insurance
Panel A – Conditional mean equation					
Constant		0.0005***	0.0003**	−0.0003***	−0.0006***
Foreign stock returns		0.1775***	0.0638***	0.5052***	0.0841***
Interest rate		−0.0158*	−0.0248*	0.0055	−0.0018
Exchange rate		−0.1050***	−0.0162	−0.0100	0.0175
Earthquake	0	−0.0000	−0.0009	−0.0000	−0.0022
Lags	1	−0.0000	0.0025	0.0003	−0.0001
	2	−0.0007	0.0010	0.0017	0.0021
	3	0.0023	0.0001	0.0024	0.0064**
	4	0.0017	−0.0003	0.0003	−0.0056***
	5	0.0010	−0.0026	0.0007	−0.0005
Tsunami	0	−0.0022	−0.0008	−0.0007	0.0027
Lags	1	−0.0020	−0.0053	−0.0006	−0.0013
	2	0.0005	−0.0008	−0.0008	−0.0019
	3	0.0005	−0.0038	−0.0015	0.0073***
	4	−0.0011	0.0012	0.0014	0.0081**
	5	−0.0006	−0.0000	0.0012	0.0028
Volcano eruption	0	−0.0034	0.0038	−0.0133	0.0128
Lags	1	0.0034	−0.0002	−0.0017	−0.0060
	2	0.0026	−0.0044	0.0014	−0.0093
	3	−0.0036	−0.0076***	−0.0020	−0.0043
	4	−0.0075	0.0166	−0.0042	0.0028
	5	−0.0006	−0.0196	−0.0094	−0.0111

Table 2: (continued)

Variable		US composite	US insurance	Japan composite	Japan insurance
Tropical cyclone	0	−0.0026	−0.0006	0.0015	0.0034*
Lags	1	−0.0019	0.0016	0.0001	−0.0014
	2	−0.0005	−0.0002	−0.0001	−0.0004
	3	0.0009	−0.0004	0.0007	0.0027
	4	−0.0023	0.0007	0.0015	0.0010
	5	−0.0000	−0.0003	−0.0003	0.0003
Panel B – Conditional variance equation					
β_0		−0.1855***	−0.2076***	−0.3859***	−0.2880***
β_1		0.1147***	0.1618***	0.1753***	0.1946***
β_2		−0.0666***	−0.0552***	−0.0879***	−0.0511**
β_3		0.9897***	0.9900***	0.9709***	0.9827***
Earthquake	0	−0.2836	0.0082	−0.0714	0.4999
Lags	1	0.5896	0.1603	0.3516	−0.3600
	2	0.3219	−0.4301	−0.2311	−0.2023
	3	−0.5869	0.2822	−0.1374	0.0063
	4	−0.3125	−0.0856	−0.3016	−0.6986
	5	0.2101	0.0442	0.2328	0.6690**
Tsunami	0	−0.7615	−0.1251	−0.0190	−0.3920
Lags	1	0.3544	−0.6263	0.0161	0.2671
	2	−0.4665	0.2969	−0.2242	−0.1137
	3	0.3249	−0.0198	0.1442	−0.2523
	4	−0.6269	0.0074	0.3216	1.2221*
	5	1.1523	0.4839	−0.3705	−0.7986*
Volcano eruption	0	0.1773	0.7490	1.0014	0.0205
Lags	1	0.7234	−0.1913	−1.5919	−0.2727
	2	−0.9673	0.0106	0.6601	0.5483
	3	−2.1309	−2.9486	−2.2944	−0.0464
	4	2.3135	3.6863**	1.0534	−2.3648
	5	−0.2366	−0.6937	0.9813	0.0537
Tropical cyclone	0	−0.1635	0.1696	−0.1132	−0.2470
Lags	1	0.7149**	−0.2583	−0.1374	0.1791
	2	−0.3591	0.4261	0.2896	−0.0001
	3	−0.3592	−0.4271	−0.0298	−0.0280
	4	−0.0676	0.0221	−0.3388	0.1243
	5	−0.2554	0.0941	0.2442	−0.1062
Panel C – Diagnostic tests					
Log-likelihood		16813.3	14384.1	14896.1	13664.9
$Q^1(10)$ Serial Correlation		10.35	8.02	4.82	7.13
$Q^2(10)$ Arch Effects		5.18	2.94	8.62	21.77***

Notes:
***, **, * denote significance level at 1%, 5%, and 10% levels, respectively.
Foreign stock returns, the interest rate, and the exchange rate are expressed in terms of one-day lag to deal with the potential endogeneity bias.
Foreign stock returns refer to the US and Japan composite (insurance) index returns when the dependent variables are Japan and US composite (insurance) index returns, respectively.
All equations include up to five lags of the dependent variable to deal with the autocorrelation in the residuals. These results are not reported due to space considerations.

Wealth effects in the US

In Table 2, results for US composite market and insurance sector returns show that movements in the Japanese stock market are significant at the 1% level or better. A 10% increase in Japanese composite market stock returns increases US composite market stock returns by 1.775%, *ceteris paribus*, while a 10% increase in Japanese insurance sector stock returns increases US insurance sector stock returns by 0.638%, *ceteris paribus*. Domestic interest rate hikes have a negative impact on both US composite market and insurance sector returns, while exchange rate changes affect only US composite market returns. A 10% appreciation in US dollar decreases US composite market return by 1.05% since appreciation of US dollar discourages foreign capital flowing into US stock market.

None of the natural disasters has any wealth effects on composite stock market returns in the US, indicating that the market effectively diversifies away the impact of natural disasters. For the US insurance sector, among all natural disasters, only the volcanic eruption is statistically significant at lag 3 and its impact is negative at the 1% level or better. This negative coefficient shows that there is a 0.76% daily drop in stock returns in the insurance sector three trading days after the volcanic eruption is announced. The reason for late adjustment might be that claims are made with some delay and/or it may take some time to collect information about volcanic eruption's true damage.

Wealth effects in the Japan

Like the US market, none of the natural disasters have any wealth effects on composite stock market returns in Japan, indicating that the market diversifies away the impact of natural disasters. For the Japanese insurance sector, all natural disasters, save the volcanic eruption, have a significant impact. Lags 3 and 4 of both earthquakes and tsunamis are statistically significant while tropical cyclone at the event date is statistically significant. Three days following earthquakes there is a 0.64% daily gain in stock returns in the insurance sector but this is corrected the next day with a 0.56% daily loss and the net impact is positive. Three days following the tsunami there is a 0.73% daily gain in stock returns in the insurance sector and gains continue the next day with an additional daily gain of 0.81%. On the day of the tropical cyclones, there is a 0.34% daily gain in stock returns in the insurance sector. The results for the Japanese insurance sector are interesting because, besides significant adjustment effects, they also indicate some supporting evidence for the 'gaining from loss hypothesis' associated with earthquakes, tsunamis, and tropical cyclones.

Risk effects in the US

Panel B reports the results for the conditional variance or risk of all returns for both the US and Japan. All beta coefficients are statistically significant, indicating significant asymmetric effects of shocks and quite persistency in the conditional variance. An important question is whether natural disasters contribute to the movements in the conditional variance of returns. For US composite market returns, only statistically significant natural disaster variable that is of tropical cyclones and at lag 1. After one day of tropical cyclones there is a significant increase (0.71 units) in the conditional variance of US composite market returns. In the US insurance sector, only natural disaster variable that is significant is of volcanic eruptions and at lag 3. After three days of volcanic eruptions there is a significant increase (3.68 units) in the conditional variance of US insurance sector returns.

Risk effects in Japan

For Japanese composite market returns, none of the natural disaster variables has any statistically significant impact on the conditional variance of the returns. In the Japanese insurance sector, both earthquakes and tsunamis are associated with statistically significant changes in the conditional variance of insurance sector returns. After five days of earthquakes there is a significant increase (0.66 units) in the conditional variance of Japanese insurance sector returns. After four days of tsunamis there is a significant increase (1.22 units) in the conditional variance of Japanese insurance sector returns. However, in the next day there is a 0.79 units decline in the conditional variance of Japanese insurance sector returns, indicating some market adjustment.

Diagnostic tests reported in Panel C indicate all models do not suffer from serial correlation and there are no remaining ARCH effects. The only exception is the model for the Japanese insurance sector that suffers from some remaining ARCH effects.

In summary, our results suggest that both US and Japanese composite returns are not affected by any of natural disasters in our sample, but the insurance sector in both countries are not able to diversify away the impact of natural disasters. Regarding the risk effects, only the Japanese composite market is immune to natural disasters, while the conditional volatility of returns of Japanese insurance sector and returns of both composite market and insurance sector in the US all are affected by natural disasters.

Our results can be best compared with Worthington and Valadkhani (2004) and Worthington (2008) for the Australian stock market. Worthington and Valadkhani (2004) report significant wealth effects and show that the net wealth effects can be positive and/or negative depending on the adjustment in the days that follow natural disasters. Our results for the Japanese insurance sector are quite consistent with their findings.

Worthington (2008) reports no significant impact of natural disasters on Australian stock market returns. The shocks do not create systematic risk in the market, and they are diversified away at the market level. Our results for Japanese and the US composite market returns are consistent with this study.

CONCLUSIONS AND IMPLICATIONS

This study provides evidence on the impact of natural disasters on both the insurance sector and the composite stock market in Japan and the US. We find no wealth effects in both the US and Japanese composite stock markets as returns in these markets are not affected by any of natural disasters in our sample. However, there are significant wealth effects in the insurance sector in both countries. The results for the Japanese insurance sector indicate evidence for the 'gaining from loss hypothesis' associated with earthquakes, tsunamis, and tropical cyclones, while there is evidence against this hypothesis in the US insurance sector. As far as the risk effects of natural disasters, except the Japanese composite market, all returns are affected by natural disasters.

There are also significant adjustment effects in returns in the Japanese insurance sector. A possible reason for this finding is the higher frequency of natural disasters in Japan compared with the US.

This study has important implications for investors since Japan and the US face high probability of future natural disasters. Generally, our results suggest that investors do not have to panic when there are natural disasters in both Japan and the US, because the impact is diversified away at the *market* level in both countries, although the insurance sector in the US does suffer from natural disasters while the Japanese insurance sector gains.

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