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# NATURAL DISASTERS — BLESSINGS IN DISGUISE?

HARDJO KOERNIADI*
*Department of Finance*
*Faculty of Business and Law*
*Auckland University of Technology*
*42 Wakefield Street*
*Auckland 1010, New Zealand*
**hkoernia@aut.ac.nz*

CHANDRASEKHAR KRISHNAMURTI
*University of Southern Queensland*
*Queensland, Australia*

ALIREZA TOURANI-RAD
*Auckland University of Technology*
*Auckland, New Zealand*

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This study examines the impact of natural disasters on stock market returns and on industries that are likely to be affected by such disasters. We find that different natural disasters have different effects on stock markets and industries. Our evidence suggests that while earthquakes, hurricanes and tornadoes could negatively affect market returns several weeks after the events, other disasters such as floods, tsunamis and volcanic eruptions have limited impact on stock markets. We also find that construction and materials industry is generally positively affected by natural disasters but non-life and travel industries are likely to suffer negative effects.

*Keywords*: Natural disasters; market returns; construction industry; non-life insurance industry; travel and leisure industry; cumulative abnormal returns.

JEL Classification: G14, G15



## 1. Introduction

Natural disasters, such as earthquakes, floods, hurricanes, tsunamis, tornadoes or volcanic eruptions, can have huge impacts on human lives and environment. The recent 2011 Japanese tsunami, for example, not only destroyed almost everything in its path causing billions of dollars of damages, but also killed thousands. It is generally believed that due to global warming, the magnitude and the frequency of occurrence of weather related

* Corresponding author.

natural disasters are to increase in the coming decades. Weather researchers from Oxford University and the Met Office predict that:

> "*…20th-century industrial emissions made the natural disaster almost twice as likely. ...It was concluded that the chances of floods occurring had increased by more than 20 percent, perhaps as much as 90 percent*" (Top end cleaning up after 600 mm of rain in storm, 2011).

Their prediction was recently confirmed by an international panel of climate scientists who reiterated that more extreme weather-related disasters are expected and that no corner of the globe is immune from them (Scientists forecast weather disasters, places at risk, 2012).

Despite massive damages to the economy of the affected country, the research on the effects of natural disasters on the stock market is scarce. The limited available results of the impact of natural disasters on stock markets of countries involved are surprisingly reported to be either short-term or insignificant. This is in contrast with the effects of other types of disasters such as terror attacks, wars, nuclear plant accidents, diseases and military related disasters that are reported to have negative effects on stock markets (see for example, Berkman *et al.*, 2010; Chen *et al.*, 2007; Chen and Siems, 2004; Carter and Simkins, 2004; Bradford and Robison, 1997; Fields and Janjigian, 1989; Hill and Schneeweis, 1983; Bowen *et al.*, 1983).

To our knowledge, there are only three studies that investigate the effects of one or another natural disaster on stock market returns. Firstly, Worthington and Valadkhani (2004) report that natural disasters occurring in Australia have different impact on the Australian stock market. They find that the Australian stock market shows no significant reaction to floods and storms, reacts positively to bushfires four days after the event, but negatively to earthquakes and cyclones for two days after the event. The immediate negative market reaction to earthquakes changes from negative to positive five days after the event. Secondly, Brounrn and Derwal (2010), investigating the impact of earthquakes on international stock market returns, report generally insignificant results. Thirdly, a recent study suggests that Japanese individual and foreign investors' trading behavior in the Tokyo Stock Exchange was significantly influenced by the Great East Japan Earthquake (Hood *et al.*, 2013).

We posit that the insignificant and mixed impact of natural disasters on stock market return may be attributed to the offsetting effects of natural disasters on different industries. In fact, an industry may even benefit from a natural disaster, while another may suffer from it, causing the overall effects of the disasters on different industries to offset each other, thus resulting in an insignificant impact on the overall market returns. For example, firms in the construction and materials industry are expected to benefit from natural disasters as demand for their products and services may increase while firms in travel and insurance industries may suffer in the aftermath of disasters. Therefore, focusing only on overall stock market returns may not produce a clear picture of the effects of natural disasters on capital markets.

Only few studies investigate the effect of a particular natural disaster on a specific industry and these are mainly based on the US experience. Their findings are quite specific to a particular event and also far from settled. Shelor *et al.* (1990, 1992) find that Loma

Prieta earthquake in the US has a negative impact on local real estate firms but interestingly had a positive effect on insurance companies. Cagle (1996) reports that insurance companies with greater exposure to Hurricane Hugo experience a negative price reaction. Brunette (1995) finds that hurricane Andrew has no significant impact on the property return index. Lamb (1998) documents that property and casualty (P&C) companies react negatively to the hurricane Andrew but not to hurricane Hugo. Finally, Huang *et al.* (2007) observe that the impact of Boxing Day tsunami on travel and construction industries in Thailand is partially significant.

Our study is different from previous studies in several aspects. First, in our study, we include several types of natural disasters such as earthquake, hurricane, tornado, flood, tsunami and volcanic eruption that have occurred in several countries. Second, in addition to stock market returns, we also investigate the specific effects of these disasters on returns of several industries that are most likely to be affected by natural disasters, such as construction and materials, non-life insurance and travel industries. Construction and materials industry is expected to gain from natural disasters as damaged properties and infrastructures need to be replaced. Evidence consistent with this view is documented by Skidmore and Toya (2002) who find that a country's gross domestic product (GDP) generally increases following cyclones, hurricanes, floods and tornadoes. The increase in GDP is expected as these disasters provide an opportunity to update the damaged capital stock (Skidmore and Toya, 2002). The effects of disasters on non-life insurance and travel firms, however, are unclear. While these firms are expected to incur large losses due to claims from policy holders, these companies may at the same time benefit from higher premiums (Shelor *et al.*, 1992; Cagle, 1996). Similarly, even though the number of travellers may decrease as people cancel their travel to the affected destination, travelling may also increase as people flee from the affected location. Third, while previous studies examine the effects for a few days after the events, we observe a longer time period (up to 40 days) as it may take a longer time for the information on the effects of the disasters to be fully absorbed by market participants (Worthington and Valadkhani, 2004).

We find that different types of natural disasters have different effects on different industries. The construction and materials industry is observed to react positively to earthquakes, hurricanes, tornadoes and tsunamis but not for earthquakes, tornadoes and tsunamis. On the other hand, non-life insurance and travel and leisure firms react negatively to earthquakes, tornadoes and tsunamis but not to hurricanes. Our evidence also suggests that the overall market returns are negatively affected by earthquakes, hurricanes and tornadoes but may not be affected by floods, tsunamis and volcanic eruptions in the long-term.

Given the expected increase in the magnitude and frequency of occurrence of natural disasters in the coming years, the findings of our study are expected to contribute to the under-researched literature on the impacts of natural disasters on stock returns by giving more insights on the direction and magnitude of different types of natural disasters on different industries occurring in several countries. Our results also suggest that investors could benefit when natural disasters strike by taking a long position in the construction and material industry and/or a short position in non-life insurance and travel industries.

The rest of the paper is organized as follows. In Section 2, we explain the data and the methodology employed. In Section 3, we present the results. Our conclusions are presented in Section 4.

## 2. Data and Methodology

The natural disasters covered in our study include earthquakes, hurricanes, tornadoes, floods, tsunamis and volcanic eruptions. Our study covers disasters that occurred in several countries with substantial damages to infrastructures and properties. We include natural disasters that are reported to have caused substantial damage on infrastructures/properties and are estimated to cost more than US$ 10 million.[1]

Data on natural disasters such as the types, their event dates and the estimated amount of damages are sourced from various newspapers and other published media such as US National Climatic Data Centre, City Council, US National Oceanic and Atmosphere Administration, MunichRe, EM-DAT and Wikipedia.

We examine the returns of domestic market index and of firms in construction and materials, non-life insurance and travel and leisure industries as these firms are expected to be mostly affected by natural disasters. Price data are collected from Datastream database.[2]

Table 1 presents the details of selected natural disasters by date in our sample causing substantial damages occurring from 1974 to 2010.

Table 1. Natural Disasters by Date

| Event Category | Event Date | Name | Country | Estimated Damges[11] |
|---|---|---|---|---|
| Tornado | 3/04/1974 | Super Outbreak | US | US$3.5 billion |
| Flood | 31/07/1976 | Big Thompson | US | US$40 million |
| Volcanic Eruption | 18/05/1980 | Mt. St. Helen | US | US$0.86 billion |
| Earthquake | 23/11/1980 | Irpinia | Italy | US$20 billion |
| Hurricane | 21/09/1989 | Hugo | US | US$10 billion |
| Earthquake | 17/10/1989 | Loma Prieta | US | US$6 billion |
| Earthquake | 28/12/1989 | Newcastle | Australia | A$4 billion |
| Tornado | 28/08/1990 | Plainfield | US | US$165 million |
| Earthquake | 20/10/1991 | Uttarkashi | India | 42,400 houses |
| Hurricane | 24/08/1992 | Andrew | US | US$26.5 billion |
| Hurricane | 12/03/1993 | Storm of the Century | US | US$11 billion |
| Earthquake | 17/01/1994 | Northridge | US | US$44 billion |
| Earthquake | 17/01/1995 | Kobe | Japan | US$100 billion |

[1] Thus, natural disasters occurring in countries such as Iraq and Iran are not included in the sample, mainly due to non-availability of reliable stock market data.

[2] Ince and Porter (2006) find that return variables provided by Datastream contain some errors. In our study, we follow their procedure to calculate stock returns from price variables.

Table 1. (*Continued*)

| Event Category | Event Date | Name | Country | Estimated Damges[11] |
|---|---|---|---|---|
| Flood | 8/05/1995 | Louisiana | US | US$1 billion |
| Flood | 5/02/1996 | Willamette Valley | US | >US$0.5 billion |
| Flood | 18/04/1997 | Red River | US | US$3.5 billion |
| Tornado | 31/05/1998 | Late May Outbreak | US | US$83 million |
| Tornado | 3/05/1999 | Oklahoma Tornado Outbreak | US | US$1.9 billion |
| Hurricane | 4/06/2001 | Tropical Storm Allison | US | US$5.5 billion |
| Hurricane | 13/08/2004 | Hurricane Charley | US | US$16.3 billion |
| Hurricane | 2/09/2004 | Hurricane Frances | US | US$12 billion |
| Hurricane | 16/09/2004 | Hurricane Ivan | US | US$18 billion |
| Tsunami | 26/12/2004 | Boxing Day Tsunami | India | US$10 billion in several countries |
| Tsunami | 26/12/2004 | Boxing Day Tsunami | Thailand | US$10 billion in several countries |
| Tsunami | 26/12/2004 | Boxing Day Tsunami | Indonesia | US$10 billion in several countries |
| Hurricane | 23/08/2005 | Hurricane Katrina | US | US$125 billion |
| Hurricane | 21/09/2005 | Hurricane Rita | US | US$16 billion |
| Tornado | 9/03/2006 | Outbreak Sequence | US | More than US$1 billion |
| Earthquake | 4/09/2010 | Christchurch NZ | New Zealand | US$30 billion |
| Flood | 27/12/2010 | Queensland | Australia | A$30 billion |

[11]Estimates on damages are sourced from MunichRe, EM-DAT and various other data sources.

We cover a total of 30 events. There are seven earthquakes that occurred in the US, India, Italy, Japan, Australia and New Zealand in our sample.[3] We also include nine hurricanes and five tornadoes that occurred in the US, four floods in the US and one flood that recently occurred in Australia in December 2010, the Boxing Day tsunami affecting India, Thailand and Indonesia,[4] and one volcanic eruption in the US. The damages caused by these disasters range from US$40 million to more than US$80 billion. It is difficult to estimate the precise date of damage due to a hurricane as it can last for days, therefore, the event dates for hurricanes are based on when the hurricanes made landfalls.

We exclude US firms with stock price less than $5 to avoid small firm effects and winsorize the sample at the 1% and 99%.[5] Table 2 presents the number of observations

[3]Two earthquakes that occurred in Mexico in 1973 and 1985 are not included as price data of Mexican firms in those years are not available from Datastream.

[4]This tsunami also affects Sri Lanka. However, we do not include this country as we believe that this country's stock market is relatively less developed than the other countries.

[5]Including these small firms and not trimming the sample would result in large cumulative abnormal positive stock returns. Including returns of these small firms could also increase noise in abnormal returns. The results are qualitatively similar when these firms are included in the sample and are available upon request. This procedure is common in studies involving US firms.

Table 2. Firm Year Observations

| | Construction and Materials | Non-life Insurance | Travel and Leisure | Total |
|---|---|---|---|---|
| Earthquake | 519 | 241 | 500 | 1,260 |
| Hurricane | 1,031 | 1,414 | 2,297 | 4,742 |
| Tornado | 522 | 374 | 1,038 | 1,934 |
| Flood | 401 | 452 | 790 | 1,643 |
| Tsunami | 228 | 24 | 63 | 315 |
| Volcanic Eruption | 48 | 27 | 58 | 133 |
| Total | 2,749 | 2,532 | 4,746 | 10,027 |



by type of disaster and industry. In total, there are 10,027 firm year observations. 1,260 of them are from earthquakes, 4,742 from hurricanes, 1,934 from tornadoes, 1,643 from floods, 315 from tsunami and 133 from volcanic eruption. Industry wise 2,749 are from the construction and material industry, 2,532 from non-life insurance and 4,746 observations are in travel and leisure industries.

Prior studies in this literature usually use an event study[6] to observe the impacts of natural disasters on a particular stock market index or industry. An exception is Worthington and Valadkhani (2004) who use an autoregressive moving average analysis. A disadvantage of using this analysis, however, is that this method is valid only when the time series is stationary which may be true in a very short period (2–5 days in their study). However, the information represented by these events may not be complete in such a short time period but may take a longer time period to be fully absorbed by the market participants (Worthington and Valadkhani, 2004, p. 2185). As our study observes the effects of natural disasters up to 40 days after the events, we believe that an event study methodology is more appropriate to examine the effects of natural disasters on these selected industries.

An event study methodology is a statistical method to measure the effect of an event on the normal and abnormal returns of a stock price. In general, abnormal returns are measured as (1) mean-adjusted returns, (2) market-adjusted returns and (3) the residuals of a market model. In the mean-adjusted return model, the normal return of a stock is estimated as the average returns of the stock over a period before a particular event occurs. The abnormal return is calculated as actual return − market return.

In the Market Model Method, the normal return of a stock is estimated in a period before an event of interest occurs using the following regression:

$$r_{jt} = \alpha_j + \beta_j \mathrm{rm}_t + \varepsilon_{jt}, \tag{1}$$

where $r_{jt}$ is the return of stock $j$ at time $t$, $\mathrm{rm}_t$ is the return on a market index and $\varepsilon_{jt}$ is a statistical error of stock $j$ at time $t$. The statistical estimates from regression (1), $\alpha_j$ and $\beta_j$, are used to estimate normal returns during an event window and the abnormal return of the stock is the difference between the actual stock return and the fitted value from

[6]This methodology is also used to investigate the effects of other events such as SARS outbreak, terrorism and military expansion on market and industry returns (Chen *et al.*, 2007; Brounrn and Derwall, 2010; Chen and Siems, 2004).

regression (1). As $\alpha_j$ is usually small and close to zero, and the average $\beta_j$ is one, the normal return of a stock can be estimated using the following model: $r_{jt} = \mathrm{rm}_t$, also known as the market-adjusted return model. The literature suggests that the mean-adjusted return model is inferior to the market-adjusted and the market models and that the market-adjusted and the market models have equal statistical power (Chandra *et al.*, 1990; Klein and Rosenfeld, 1987).

As mentioned earlier, it is difficult to estimate the precise event date of disasters such as hurricanes and floods as it takes days for these disasters to start causing damages on properties and infrastructures. Moreover, small tornadoes occur almost every year in certain parts of the US making it difficult to estimate the period of normal stock returns. Therefore, to estimate a stock's abnormal return, we do not employ a market model but a market-adjusted return model which was also commonly used in previous studies such as Al Rahahleh and Wei (2012). Employing a market-adjusted return model is also expected to lessen the contamination effects from macroeconomic events that are independent of the disasters on the industries' returns (Worthington and Valadkhani, 2004). The market-adjusted return model is as follows:

$$AR_{it} = R_{it} - R_{mt}, \tag{2}$$

where $AR_{it}$ = abnormal return of stock $i$ at time $t$,
$R_{it}$ = return of stock $i$ at time $t$,
$R_{mt}$ = return of domestic stock market index at time $t$.

The market index used is the major domestic market index of the country in which a disaster occurs and returns are calculated using local currencies. Following Brown *et al.* (1988) and Shelor *et al.* (1992), the test statistics used to test the cumulative abnormal return (CAR) is:

$$t\text{-stat} = (\mathrm{CAR}_t)/(\mathrm{var}\,\mathrm{CAR}_t)^{1/2}. \tag{3}$$

## 3. Results and Discussion

Table 3 presents the total returns and abnormal returns of the markets and the three industries in reaction to all natural disasters.[7] On the event day (day 0), construction industry is positively affected by natural disasters but non-life insurance and travel industries experience negative returns. These conflicting reactions across industries could create an offsetting effect on the overall market returns and may explain insignificant market reaction to natural disasters observed in previous studies. The CARs for construction and materials industry are positive and significant until 40 days after the event.

[7] The abnormal returns are stationary according to the Augmented Dickey–Fuller tests and on average structural breaks occur from day 0 to +2 for each industry according to the Bai–Perron tests. The results are available from the authors upon request.

Table 3. Market and Industry Reactions to All Natural Disasters

| | AR % | CAR % | | | |
|---|---|---|---|---|---|
| Day | 0 | 0,+3 | 0,+10 | 0,+30 | 0,+40 |
| Market | 0.09 | 0.28*** | 0.59** | 0.68** | 2.47*** |
| Construction and Materials | 0.24*** | 0.97*** | 2.51*** | 2.94*** | 2.94*** |
| Non-life Insurance | −0.12*** | −0.22*** | 0.00 | 1.23*** | 1.05** |
| Travel and Leisure | −0.21*** | −0.21*** | 0.08 | 0.27 | 0.50* |

*Notes:* AR is abnormal returns calculated from the market-adjusted model, CAR is cumulative abnormal returns. *significant at 10%, **significant at 5% and ***significant at 1%.



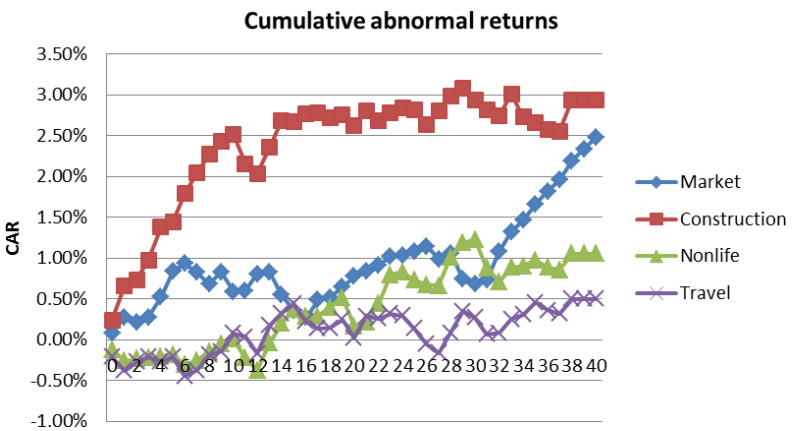


Figure 1. Cumulative Abnormal Returns After the Events

For non-life insurance and travel industries, the abnormal returns are negative at least three days after the event takes place. Figure 1 shows that non-life insurance and travel industries experience positive return around 12 days after the event. The positive market reaction for 40 days may be driven by positive returns from construction and materials industry and non-life and travel industries 30 days after the event.

Table 4 presents descriptive statistics of the event day's returns and CARs of the market and the industries, 3, 10, 30 and 40 days, respectively after the events, sorted by the type of natural disasters. On average, market reactions to natural disasters on the event day are positive except to earthquakes and hurricanes. There are some interesting patterns when we categorize on the basis of industry. Firms in the construction industry react positively to natural disasters on the event day except to volcanic eruptions. Non-life insurance industry reacts negatively on the event day except to tsunamis and travel industry reacts negatively except to earthquakes. In general, construction industry firms have positive CARs over several windows up to (0, +40) reflecting the possibility of future benefits to the industry due to rebuilding of the infrastructure destroyed in the natural disaster. Overall, firms in the non-life insurance sector have negative CARs over several windows up to (0, +40). These

Table 4. Descriptive Statistics of CAR

| Panel A | MARKET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 | | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
| Earthquake | | | | | | Hurricanes | | | | | |
| Mean | −0.12% | −0.46% | 0.19% | −1.31% | 1.48% | Mean | −0.15% | 0.12% | −0.17% | −1.02% | 0.14% |
| SD | 0.90% | 2.75% | 5.02% | 5.40% | 11.61% | SD | 0.72% | 1.51% | 2.44% | 2.50% | 3.61% |
| Min | −1.69% | −5.73% | −9.15% | −12.11% | −16.84% | Min | −1.00% | −1.61% | −4.18% | −4.49% | −4.42% |
| 1st Quartile | −0.40% | −1.27% | −1.64% | −2.10% | −4.05% | 1st Quartile | −0.86% | −1.19% | −1.30% | −2.52% | −2.37% |
| Median | −0.20% | 0.58% | 1.41% | −1.67% | 2.92% | Median | −0.31% | −0.31% | −0.50% | −0.85% | 0.29% |
| 3rd Quartile | 0.30% | 1.20% | 3.37% | 2.49% | 6.00% | 3rd Quartile | 0.28% | 0.94% | 1.21% | 0.27% | 2.27% |
| Max | 1.24% | 2.05% | 5.63% | 3.81% | 20.38% | Max | 1.12% | 2.98% | 4.13% | 3.78% | 5.68% |
| Tornado | | | | | | Flood | | | | | |
| Mean | 0.40% | 0.25% | 0.37% | −0.81% | 0.40% | Mean | 0.49% | 1.48% | 2.26% | 4.64% | 6.75% |
| SD | 0.82% | 0.84% | 1.07% | 5.97% | 3.70% | SD | 0.50% | 1.21% | 2.89% | 4.39% | 6.41% |
| Min | −0.49% | −0.77% | −1.21% | −6.54% | −4.44% | Min | −0.24% | 0.40% | 0.69% | 0.53% | 2.46% |
| 1st Quartile | −0.03% | −0.20% | 0.38% | −5.50% | −2.46% | 1st Quartile | 0.39% | 0.71% | 0.76% | 2.09% | 2.99% |
| Median | 0.01% | 0.37% | 0.40% | −2.38% | 1.47% | Median | 0.67% | 1.19% | 0.87% | 3.67% | 4.17% |
| 3rd Quartile | 1.05% | 0.38% | 0.48% | 2.58% | 3.69% | 3rd Quartile | 0.77% | 1.96% | 2.37% | 6.22% | 7.92% |
| Max | 1.46% | 1.49% | 1.81% | 7.79% | 3.73% | Max | 0.88% | 3.14% | 6.59% | 10.70% | 16.21% |
| Tsunami | | | | | | Volcanic Eruption | | | | | |
| Mean | 0.15% | 0.48% | 1.14% | 5.58% | 6.71% | Mean | 0.30% | 1.54% | 2.94% | 6.93% | 10.99% |
| SD | 1.05% | 0.86% | 3.42% | 4.00% | 4.91% | SD | N/A | 0.56% | 0.86% | 0.82% | 0.84% |
| Min | −0.97% | −0.33% | −2.76% | 1.41% | 1.04% | Min | 0.30% | −0.05% | −1.60% | −1.60% | −1.60% |
| 1st Quartile | −0.34% | 0.02% | −0.10% | 3.67% | 5.27% | 1st Quartile | 0.30% | 0.06% | −0.14% | −0.19% | −0.23% |
| Median | 0.29% | 0.37% | 2.57% | 5.93% | 9.49% | Median | 0.30% | 0.20% | 0.30% | 0.25% | 0.28% |
| 3rd Quartile | 0.70% | 0.88% | 3.09% | 7.66% | 9.55% | 3rd Quartile | 0.30% | 0.52% | 0.79% | 0.65% | 0.71% |
| Max | 1.12% | 1.39% | 3.61% | 9.39% | 9.60% | Max | 0.30% | 1.20% | 1.48% | 1.90% | 1.90% |

Table 4. (*Continued*)

| Panel B | CONSTRUCTION AND MATERIALS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 | | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
| Earthquake | | | | | | Hurricanes | | | | | |
| Mean | 1.39% | 3.64% | 8.00% | 6.21% | 7.12% | Mean | 0.14% | 0.51% | 1.45% | 1.78% | 0.93% |
| SD | 3.73% | 6.86% | 13.28% | 12.48% | 13.18% | SD | 3.25% | 4.37% | 7.50% | 11.47% | 12.27% |
| Min | −11.33% | −11.01% | −22.48% | −29.89% | −28.22% | Min | −43.01% | −14.73% | −29.15% | −39.78% | −36.76% |
| 1st Quartile | 0.02% | −1.14% | −1.31% | −2.05% | −1.47% | 1st Quartile | −1.09% | −1.74% | −2.31% | −4.67% | −5.89% |
| Median | 0.46% | 2.56% | 5.68% | 6.26% | 7.20% | Median | −0.06% | 0.28% | 1.00% | 1.24% | 0.58% |
| 3rd Quartile | 2.44% | 7.72% | 15.81% | 15.16% | 16.64% | 3rd Quartile | 0.91% | 2.40% | 5.07% | 8.05% | 7.70% |
| Max | 27.10% | 29.48% | 58.45% | 42.04% | 41.88% | Max | 30.00% | 24.42% | 39.59% | 44.34% | 43.14% |
| Tornado | | | | | | Flood | | | | | |
| Mean | 0.15% | 0.96% | 0.94% | 1.37% | −1.33% | Mean | 0.13% | −0.56% | −0.89% | −0.95% | −1.60% |
| SD | 3.05% | 4.72% | 6.28% | 11.40% | 14.51% | SD | 3.25% | 4.91% | 7.20% | 10.41% | 11.30% |
| Min | −11.36% | −18.22% | −20.05% | −28.30% | −74.47% | Min | −13.42% | −16.34% | −25.66% | −30.85% | −32.52% |
| 1st Quartile | −1.21% | −1.59% | −3.05% | −6.42% | −9.85% | 1st Quartile | −0.88% | −3.10% | −5.17% | −6.83% | −9.02% |
| Median | 0.24% | 0.59% | 0.56% | 1.48% | −0.81% | Median | −0.07% | −0.92% | −0.75% | −1.79% | −2.30% |
| 3rd Quartile | 1.07% | 3.13% | 4.48% | 8.88% | 7.07% | 3rd Quartile | 0.88% | 1.20% | 2.89% | 4.55% | 4.80% |
| Max | 27.76% | 24.33% | 21.79% | 33.60% | 42.46% | Max | 24.40% | 19.73% | 22.69% | 35.55% | 34.12% |
| Tsunami | | | | | | Volcanic Eruption | | | | | |
| Mean | 0.26% | 1.06% | 5.55% | 7.69% | 7.03% | Mean | −0.22% | −1.17% | −0.41% | −0.35% | 3.17% |
| SD | 2.03% | 4.24% | 7.93% | 13.74% | 13.11% | SD | 2.39% | 3.94% | 4.77% | 6.47% | 8.04% |
| Min | −4.59% | −6.58% | −6.26% | −10.48% | −9.91% | Min | −3.38% | −7.89% | −10.81% | −12.41% | −12.39% |
| 1st Quartile | −0.29% | −0.37% | 2.76% | −1.41% | −1.04% | 1st Quartile | −1.52% | −2.71% | −3.09% | −5.39% | −2.20% |
| Median | −0.29% | −0.37% | 2.76% | 0.50% | −0.28% | Median | −0.30% | −1.53% | −1.16% | −0.04% | 2.65% |
| 3rd Quartile | 0.36% | 1.23% | 7.40% | 14.30% | 11.25% | 3rd Quartile | 0.14% | −0.45% | 2.44% | 5.46% | 7.53% |
| Max | 9.69% | 17.71% | 42.43% | 62.92% | 60.48% | Max | 10.16% | 15.95% | 10.01% | 12.75% | 22.80% |

Table 4. (*Continued*)

| Panel C | NON-LIFE INSURANCE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 | | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
| Earthquake | | | | | | Hurricanes | | | | | |
| Mean | −0.06% | −0.12% | −0.14% | 1.00% | −0.17% | Mean | −0.07% | 0.03% | 0.26% | 1.92% | 1.74% |
| SD | 2.34% | 3.44% | 5.15% | 8.88% | 9.48% | SD | 1.88% | 2.86% | 4.57% | 7.75% | 9.02% |
| Min | −6.30% | −9.33% | −13.41% | −27.90% | −22.79% | Min | −9.28% | −9.26% | −13.94% | −22.22% | −25.80% |
| 1st Quartile | −1.17% | −2.35% | −3.42% | −4.19% | −6.23% | 1st Quartile | −0.99% | −1.57% | −2.62% | −2.87% | −3.93% |
| Median | −0.52% | −0.39% | −0.27% | 0.64% | −0.42% | Median | −0.07% | 0.09% | 0.08% | 1.43% | 1.35% |
| 3rd Quartile | 0.71% | 1.62% | 2.79% | 6.58% | 6.14% | 3rd Quartile | 0.75% | 1.63% | 3.11% | 6.51% | 7.50% |
| Max | 14.48% | 16.57% | 12.32% | 31.57% | 24.25% | Max | 13.62% | 10.66% | 15.46% | 26.88% | 29.03% |
| Tornado | | | | | | Flood | | | | | |
| Mean | −0.36% | −0.19% | −0.49% | −1.45% | −3.34% | Mean | −0.25% | −1.02% | −1.08% | −1.24% | −1.25% |
| SD | 2.32% | 3.18% | 4.91% | 8.13% | 8.95% | SD | 1.82% | 3.34% | 4.96% | 6.71% | 7.72% |
| Min | −14.09% | −10.72% | −15.38% | −26.45% | −29.70% | Min | −7.72% | −10.68% | −15.48% | −16.58% | −19.80% |
| 1st Quartile | −1.46% | −2.01% | −3.17% | −6.70% | −8.72% | 1st Quartile | −0.98% | −3.04% | −4.33% | −5.46% | −6.25% |
| Median | −0.14% | −0.13% | −0.69% | −0.73% | −3.18% | Median | −0.52% | −1.32% | −0.84% | −1.64% | −1.25% |
| 3rd Quartile | 0.83% | 1.37% | 2.05% | 3.76% | 2.97% | 3rd Quartile | 0.52% | 0.77% | 1.80% | 2.99% | 3.88% |
| Max | 8.72% | 10.12% | 16.13% | 18.55% | 17.73% | Max | 9.02% | 10.98% | 14.95% | 22.84% | 22.36% |
| Tsunami | | | | | | Volcanic Eruption | | | | | |
| Mean | 0.40% | 1.41% | −0.88% | −4.07% | −3.84% | Mean | −0.50% | −1.91% | −2.64% | 0.21% | −0.43% |
| SD | 2.31% | 6.07% | 7.85% | 9.90% | 9.60% | SD | 1.23% | 1.83% | 2.47% | 5.02% | 4.50% |
| Min | −2.84% | −3.46% | −7.35% | −14.54% | −13.28% | Min | −2.68% | −5.42% | −8.00% | −9.96% | −8.17% |
| 1st Quartile | −1.02% | −1.43% | −4.91% | −10.19% | −10.09% | 1st Quartile | −1.10% | −3.05% | −4.32% | −4.01% | −4.02% |
| Median | −0.04% | −0.17% | −3.61% | −8.59% | −8.42% | Median | −0.30% | −1.82% | −2.56% | 0.50% | −1.06% |
| 3rd Quartile | 0.97% | 0.42% | −0.05% | 0.60% | −0.53% | 3rd Quartile | −0.07% | −1.49% | −0.99% | 3.14% | 2.79% |
| Max | 7.97% | 22.46% | 23.28% | 18.93% | 22.09% | Max | 2.89% | 2.24% | 2.01% | 10.06% | 7.65% |

Table 4. (*Continued*)

| Panel D | TRAVEL AND LEISURE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 | | Event Day | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
| Earthquake | | | | | | Hurricanes | | | | | |
| Mean | 0.21% | 0.10% | −0.84% | −0.10% | 0.67% | Mean | −0.27% | −0.04% | 0.34% | 1.27% | 1.76% |
| SD | 2.71% | 4.42% | 6.33% | 10.58% | 11.41% | SD | 2.97% | 4.54% | 7.24% | 12.40% | 14.10% |
| Min | −12.54% | −18.82% | −19.76% | −28.56% | −33.62% | Min | −27.55% | −23.15% | −26.48% | −46.43% | −43.49% |
| 1st Quartile | −0.99% | −2.06% | −4.78% | −6.91% | −6.06% | 1st Quartile | −1.34% | −2.41% | −3.43% | −5.43% | −6.49% |
| Median | 0.20% | 0.06% | −0.84% | 0.62% | 1.32% | Median | −0.22% | −0.19% | 0.39% | 1.23% | 1.38% |
| 3rd Quartile | 1.18% | 2.56% | 2.86% | 6.03% | 7.48% | 3rd Quartile | 0.86% | 2.06% | 3.90% | 7.87% | 9.54% |
| Max | 11.98% | 14.89% | 19.83% | 36.35% | 30.74% | Max | 41.08% | 25.22% | 29.36% | 53.30% | 53.57% |
| Tornado | | | | | | Flood | | | | | |
| Mean | −0.13% | −0.30% | 0.62% | −1.64% | −2.52% | Mean | −0.36% | −0.60% | −0.48% | 0.58% | 0.43% |
| SD | 3.56% | 5.48% | 8.43% | 14.60% | 15.49% | SD | 3.39% | 5.23% | 8.12% | 12.52% | 15.06% |
| Min | −20.01% | −21.13% | −26.15% | −52.68% | −47.02% | Min | −16.73% | −17.98% | −26.57% | −36.19% | −39.63% |
| 1st Quartile | −1.46% | −2.80% | −4.26% | −9.33% | −12.13% | 1st Quartile | −1.64% | −3.53% | −5.31% | −7.39% | −9.91% |
| Median | −0.01% | −0.61% | −0.20% | −1.44% | −2.64% | Median | −0.60% | −0.81% | −0.93% | −0.55% | −0.68% |
| 3rd Quartile | 0.94% | 1.94% | 4.82% | 7.26% | 7.20% | 3rd Quartile | 0.80% | 1.91% | 3.66% | 8.39% | 10.41% |
| Max | 28.50% | 28.21% | 40.44% | 47.28% | 41.65% | Max | 26.72% | 21.13% | 31.29% | 42.84% | 43.76% |
| Tsunami | | | | | | Volcanic Eruption | | | | | |
| Mean | −0.83% | −1.01% | −0.52% | −2.76% | −2.56% | Mean | −0.27% | −1.80% | −3.96% | −2.57% | −0.78% |
| SD | 1.84% | 4.65% | 5.02% | 6.01% | 6.33% | SD | 3.02% | 4.11% | 5.80% | 10.11% | 10.91% |
| Min | −7.27% | −9.45% | −10.68% | −17.04% | −13.55% | Min | −5.98% | −9.34% | −16.83% | −19.41% | −30.67% |
| 1st Quartile | −1.12% | −3.35% | −3.61% | −6.98% | −7.89% | 1st Quartile | −1.98% | −4.12% | −7.45% | −8.22% | −5.92% |
| Median | −0.29% | −0.37% | 0.75% | −1.41% | −1.08% | Median | −0.30% | −1.96% | −4.41% | −3.48% | −1.89% |
| 3rd Quartile | −0.20% | 0.33% | 2.76% | −1.39% | −1.04% | 3rd Quartile | 0.46% | 0.42% | −1.09% | 1.74% | 7.68% |
| Max | 2.79% | 22.14% | 20.96% | 11.90% | 15.39% | Max | 12.20% | 13.50% | 12.74% | 21.19% | 20.56% |

results indicate that payouts on account of the disaster exceed the benefits from future increase in premium income. An exception is the reaction to hurricanes. Travel and leisure industry also experiences negative CARs except for selected windows in some types of disasters indicating that overall natural disasters are harmful for the industry.

Table 5 presents the CARs of the market, construction, non-life insurance and travel industries for each of the disasters. Panels A and C show that market reacts negatively to earthquakes, hurricanes and tornadoes. Generally, this is consistent with Worthington and Valadkhani (2004) who report negative reaction on the event day and positive market

Table 5. CARs Sorted Based on Types of Natural Disasters

| CAR | Market | Construction | Non-life | Travel |
|---|---|---|---|---|
| Panel A. Earthquake | | | | |
| 0,+3 | −0.46%** | 3.64%*** | −0.12% | 0.10% |
| 0,+10 | 0.19% | 8.00%*** | −0.14% | −0.84% |
| 0,+30 | −1.31%*** | 6.21%*** | 1.01%** | −0.10% |
| 0,+40 | 1.48%*** | 7.12%*** | −0.17% | 0.67%*** |
| Panel B. Hurricane | | | | |
| 0,+3 | 0.12% | 0.51%*** | 0.03% | −0.04% |
| 0,+10 | −0.17% | 1.45%*** | 0.26% | 0.34%*** |
| 0,+30 | −1.02%*** | 1.78%*** | 1.92%*** | 1.27%*** |
| 0,+40 | 0.14% | 0.93%** | 1.74%*** | 1.76%** |
| Panel C. Tornado | | | | |
| 0,+3 | 0.25% | 0.96%** | −0.19% | −0.30%** |
| 0,+10 | 0.37% | 0.94%*** | −0.49%* | 0.62% |
| 0,+30 | −0.81%* | 1.37%* | −1.45%*** | −1.64%** |
| 0,+40 | 0.40% | −1.33%*** | −3.34%*** | −2.52%** |
| Panel D. Flood | | | | |
| 0,+3 | 1.48%*** | −0.56%* | −1.02%** | −0.60%*** |
| 0,+10 | 2.26%*** | −0.89%** | −1.08%** | −0.48%** |
| 0,+30 | 4.64%*** | −0.95%* | −1.24%*** | 0.58% |
| 0,+40 | 6.75%*** | −1.60%*** | −1.25%*** | 0.43% |
| Panel E. Tsunami | | | | |
| 0,+3 | 0.48%** | 1.06%*** | 1.41%** | −1.01%** |
| 0,+10 | 1.14%* | 5.55%*** | −0.88% | −0.52% |
| 0,+30 | 5.58%*** | 7.69%*** | −4.07%*** | −2.76%** |
| 0,+40 | 6.71%*** | 7.03%*** | −3.84%*** | −2.56%** |
| Panel F. Volcanic Eruption | | | | |
| 0,+3 | 1.54%*** | −1.17%** | −1.91%*** | −1.80%*** |
| 0,+10 | 2.94%*** | −0.41% | −2.64%** | −3.96%*** |
| 0,+30 | 6.93%*** | −0.35% | 0.21% | −2.57%* |
| 0,+40 | 10.99%*** | 3.17%* | −0.43% | −0.78% |

*Notes*: *Significant at 10%, **significant at 5% and ***significant at 1%.

Table 6. CARs Sorted Based on Country

| | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
|---|---|---|---|---|
| Panel A. Construction Industry | | | | |
| *Earthquake* | | | | |
| Australia | 0.18% | −0.55% | 1.34% | 5.06%*** |
| India | 0.02% | 2.39%*** | 2.50% | 4.16%** |
| Italy | 3.21%** | 2.10%* | 10.81%* | −5.25% |
| Japan | 5.78%*** | 13.56%*** | 8.91%*** | 10.52%*** |
| New Zealand | 1.60%* | 3.09%** | 2.18%** | 3.24%** |
| US | 1.59%*** | 1.30%*** | 3.36%** | 2.49%*** |
| *Flood* | | | | |
| Australia | 0.89%*** | 2.28%*** | 0.27% | 0.47% |
| US | −0.85%** | −1.53%** | −1.20%* | −2.03%*** |
| *Tsunami* | | | | |
| India | 0.65%*** | 5.26%*** | 6.30%** | 6.47%*** |
| Indonesia | 1.96%** | 4.93%** | 12.08%*** | 8.48%** |
| Thailand | 3.97%** | 10.36%** | 14.66%*** | 10.57%*** |
| Panel B. Non-life Insurance Industry | | | | |
| *Earthquake* | | | | |
| Australia | −2.79%*** | −5.25%*** | −6.79%*** | −4.49% |
| India | −5.42%** | −7.83%*** | 7.25% | 2.62% |
| Italy | 0.26% | −2.37%*** | 4.01% | 1.53% |
| Japan | −2.35%*** | −0.38% | −1.16% | 1.73% |
| New Zealand | −2.88%*** | −3.97%*** | −4.66%*** | −6.23%*** |
| US | 0.13% | 0.14% | 1.20%*** | −0.25% |
| *Flood* | | | | |
| Australia | −1.07% | −1.89% | −2.28% | 0.53% |
| US | −1.02%** | −1.07%** | −1.22%*** | −1.28%*** |
| *Tsunami* | | | | |
| India | −1.62% | 13.33%* | 11.99%** | 18.13%*** |
| Indonesia | −0.53% | −3.96%** | −9.57%*** | −8.09%*** |
| Thailand | 6.42%** | 1.66% | 3.14%** | −1.02% |
| Panel C. Tourism and Travel Industry | | | | |
| *Earthquake* | | | | |
| Australia | 0.66% | 0.38% | −3.10%* | 0.27% |
| India | 0.02% | −2.38% | 2.49% | 4.70%* |
| Italy | 3.23%*** | 4.73%*** | 29.08%** | 19.74%* |
| Japan | 0.38% | −1.37% | 0.17% | 3.98%** |
| New Zealand | 0.52% | −0.81% | 1.34% | 5.41%** |
| US | 0.09% | −0.75% | 0.22% | 0.96%** |
| *Flood* | | | | |
| Australia | 0.15% | −2.08%* | −5.01%** | −3.02% |
| US | −0.64%*** | −0.38% | 0.95% | 0.66% |

Table 6. (*Continued*)

| | CAR 0,+3 | CAR 0,+10 | CAR 0,+30 | CAR 0,+40 |
|---|---|---|---|---|
| *Tsunami* | | | | |
| India | −2.64%** | 0.86% | 0.38% | 0.82% |
| Indonesia | −0.53%*** | −3.58%** | −6.58%*** | −6.61%*** |
| Thailand | 2.76% | 0.28% | −5.69%*** | −5.81%** |

*Notes*: *Significant at 10%, **significant at 5% and ***significant at 1%.

returns five days later. Our results however, show that market returns in relation to earthquakes are negative at least 30 days after the event. Similar reactions are observed for non-life and travel industries. CARs of these industries are negative at least 10 days after the events. Construction industry however, reacts positively up to 40 days after the events. These results show that firms in different industries have different stock price reactions to natural disasters.

The market also reacts negatively to hurricanes (Panel B), but the CARs of construction, non-life and travel industries are positive more than 30 days later. Cumulative market returns, surprisingly, are positive in relation to floods, tsunamis and volcanic eruptions (Panels D–F). A possible explanation for why market returns are positive is that market returns may be affected by other events unrelated to the disasters.[8] Another possible explanation is that these disasters may not have substantial impacts to influence the markets in the affected countries.[9] Panels D–F also report that returns of non-life and travel industries are mostly negative following these disasters. Construction industry's returns are observed to be positive after a tsunami but negative after floods and volcanic eruptions which could be due to not much replacement needed for properties and infrastructures after the floods and to a limited sample size for volcanic eruption (only one event).

The results are similar when CARs are sorted based on country, as reported in Table 6.[10] On average, the construction and materials industry benefits from natural disasters. The negative CARs for flood reported in Panel D of Table 5 are driven by negative returns of US stocks in this industry. Natural disasters negatively affected stock price of non-life insurance firms in all countries in the sample except for tsunami in India and Thailand (Panel B). Floods and tsunamis are observed to negatively affect travel and tourism industry (Panel C). Earthquakes however, are reported to have positive effects 40 days after the event, across all the countries, on the average abnormal returns of this industry.

[8] Natural disasters however, occur randomly across time and countries. Thus, it is less likely that independent macroeconomic events affect market returns during window period.

[9] We also find that the cumulative market returns shortly (three days) after the events is negative (−0.38%) at the 10% significance level for natural disasters causing losses of more than US$10 billion but significantly lower than those causing less than US$10 billion suggesting that size of losses may have relevant impact on stock market returns (Hallegatte, 2008). The results are not reported but available upon request.

[10] All hurricanes and tornadoes in our sample have occurred in the US and been reported in Table 5, therefore, we do not report them again in Table 6.

Overall, it appears that stock market reaction to natural disasters varies by type of industry much more than type of disaster or by country of occurrence.

## 4. Conclusion

In this paper, we examine the impact of natural disasters on stock market returns and several industries' returns. We observe that natural disasters have different impact on market returns based on industry. These findings are important given the limited research in this literature and that prior studies in this area usually study the impact of natural disasters only on a particular market or on a specific industry.

We find that market returns one month after the event are likely to be negatively affected by earthquakes, hurricanes and tornadoes but positively by floods, tsunamis and volcanic eruptions. On average, shortly after the events, the construction industry is likely to benefit when natural disasters strike while non-life and travel industries are more likely to suffer adverse effects. Our results also suggest that investors may benefit when natural disasters strike by taking a long position in construction and material industry and/or a short position in nonlife insurance and travel industries immediately after the events.



## References

Al Rahahleh, NA and PP Wei (2012). The performance of frequent acquirers: Evidence from emerging markets. *Global Finance Journal*, 23, 16–33.

Berkman, H, B Jacobsen and JB Lee (2010). Time-varying rare disaster risk and stock returns. University of Auckland Working Paper.

Bowen, RM, RP Castanias and LA Daley (1983). Intra-industry effects of the accident at Three Mile Island. *Journal of Financial and Quantitative Analysis*, 18, 87–111.

Bradford, BM and HD Robison (1997). Abnormal returns, risk, and financial statement data: The case of the Iraqi invasion of Kuwait. *Journal of Economics and Business*, 49, 193–204.

Brounrn, D and J Derwall (2010). The impact of terrorist attacks on international stock markets. *European Financial Management*, 16, 585–598.

Brown, KC, WV Harlow and SM Tinic (1988). Risk aversion, uncertain information, and market efficiency. *Journal of Financial Economics*, 22, 355–385.

Brunette, D (1995). Natural disasters and commercial real estate returns. *Real Estate Finance*, 11, 67–72.

Cagle, JAB (1996). Natural disasters, insurer stock prices and market discrimination: The case of Hurricane Hugo. *Journal of Insurance Issues*, 19, 53–68.

Carter, DA and BJ Simkins (2004). The market's reaction to unexpected, catastrophic events: The case of airline stock returns and the September 11th attacks. *Quarterly Review of Economic and Finance*, 44, 539–558.

Chandra, R, S Moriarity and GL Willinger (1990). A reexamination of the power of alternative return-generating models and the effect of accounting for cross-sectional dependencies in event studies. *Journal of Accounting Research*, 28, 398–408.

Chen, MH, SC Jang and WG Kim (2007). The impact of the SARS outbreak on Taiwanese hotel stock performance: An event-study approach. *International Journal of Hospitality Management*, 26, 200–212.

Chen, AH and TF Siems (2004). The effects of terrorism on global capital markets. *European Journal of Political Economy*, 20, 349–366.

Fields, MA and V Janjigian (1989). The effect of Chernobyl on electric-utility stock prices. *Journal of Business Research*, 18, 81–87.

Hallegatte, S (2008). An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. *Risk Analysis*, 28, 779–799, doi: 10.1111/j.1539-6924.2008.01046.x.

Hill, J and T Schneeweis (1983). The effect of Three Mile Island on electric utility stock prices: A note. *Journal of Finance*, 38, 1285–1292.

Hood, M, A Kamesaka, J Nofsinger and T Tamura (2013). Investor response to a natural disaster: Evidence from Japan's 2011 earthquake. *Pacific-Basin Finance Journal*, 23, 240–252.

Huang, CJ, SH Ho and CY Wu (2007). The impact of the Asian tsunami attacks on tourism-related industry stock returns. *Journal of American Academy of Business*, 12, 77–82.

Ince, OS and RB Porter (2006). Individual equity return data from Thomson Datastream: Handle with care! *Journal of Financial Research*, 29, 463–479.

Klein, A and J Rosenfeld (1987). The influence of market conditions on event-study residuals. *Journal of Financial and Quantitative Analysis*, 22, 345–351.

Lamb, R. (1998). An examination of market efficiency around hurricanes. *Financial Review*, 33, 163–172.

Scientists forecast weather disasters, places at risk (2012). *New Zealand Herald*, 29 March, Available at: http://www.nzherald.co.nz/world/news/article.cfm?c_id=2&objectid=10795232.

Shelor, RM, DC Anderson and ML Cross (1990). The impact of the California earthquake on real estate firms' stock value. *Journal of Real Estate Research*, 5, 335–340.

Shelor, RM, DC Anderson and ML Cross (1992). Gaining from loss: Property-lioabilty insurer stock values in the aftermath of the 1989 California earthquake. *Journal of Risk and Insurance*, 59, 476–488.

Skidmore, M and H Toya (2002). Do natural disasters promote long-run growth? *Economic Enquiry*, 40, 664–687.

Top end cleaning up after 600 mm of rain in storm (2011). *New Zealand Herald*. Available at: http://www.nzherald.co.nz/world/news/article.cfm?c_id= 2&objectid=10707060.

Worthington, A and A Valadkhani (2004). Measuring the impact of natural disasters on capital markets: An empirical application using intervention analysis. *Applied Economics*, 36, 2177–2186.