DLSU Business & Economics Review 22.2 (2013), pp. 54-63

Natural Disasters and the Philippine Stock Exchange Index: A Garch-M Analysis

Adrian P. Galido, Ph.D.
Mindanao State University – Iligan Institute of Technology, Iligan City, Philippines
adrian.galido@g.msuiit.edu.ph

Marites A. Khanser, D.B.A.
University of San Carlos, Cebu City, Philippines
mkhanser2003@yahoo.com

This study examines the effect of earthquakes, tropical cyclones and volcanic eruptions on the Philippine Stock Exchange index (PSEi) over the period 2 January 1985 to 30 December 2010. The extant literature show varying results with respect to the "gaining from loss" hypothesis of Shelor, Anderson, and Cross (1990, 1992). With a GARCH(2,2)-M specification, support for the "gaining from loss" hypothesis was evident for earthquakes and tropical cyclones. Overall, disasters have an insignificant effect on the market returns. Future researches are directed to use methodological alternatives, consider other forms of disasters, and different level (sector or firm) of analyses. Policymakers can consider including market movements in assessing the impact of natural disasters. Investors can attempt to conceptualize disaster-based trading strategies.

Keywords: Natural disaster, stock market, PSEi, GARCH-M, gaining from loss, time series

INTRODUCTION

Several scholars have examined the link between the natural environment and movements of capital markets. Factors relating to the weather including cloud cover and precipitation (Saunders, 1993; Hirshleifer & Shumway, 2003) and temperature (Cao & Wei, 2005) have been investigated in different context. With the recent, alarming and increasing incidents of natural disasters, it is apparent that understanding the response of the stock market be undertaken.

Natural hazards can be regarded as part and parcel of the Philippine environment (National Disaster Coordinating Council [NDCC], 2009). The country's placement in the Pacific Ring of Fire explains the occurrence of earthquakes and tsunamis as well as the numerous volcanic eruptions. The country's location along the typhoon belt on the Western North Pacific Basin, where a significant percentage of tropical cyclones enter or originate, contributes to the frequent occurrence of such type of weather disturbance. As such, tropical cyclones visit the country more often than other forms of natural disasters, that is, volcanic eruptions, earthquakes, and floods.

Occasional news of weather- and geophysical-related natural disasters from across the globe on various instances typically show negative outcomes. Loss of life or injury, loss of property, socio-economic destruction, and environmental degradation are among such outcomes. Disruptions on the normal flow of businesses, although temporary, are likely to occur as well (Valle-Sison, 2009). Between 1992 and early 2011, the average value of damage derived from tropical cyclones amounted to US$31 million (Emergency Events Database [EM-DAT], 2011). It is unfortunate that the frequency and extent of events caused by natural forces such as flooding, storms, earthquakes and tidal waves, show an upward trend.

Although numerous studies have examined natural disasters and capital markets, it has not achieved mainstream status in the Philippine context. The objective, therefore, of this paper is to examine the behavior of the stock market, more specifically the Philippine composite index, to the commonly occurring forms of natural disasters in the country.

Studying the effect of natural disasters is appealing because of the potential opportunities that could arise out of figuring out such investment puzzle as well as its implications on risk management when investing. Individual and institutional investors can possibly draw or conceptualize disaster-based trading strategies. In providing a picture of how the market fluctuates in light of natural disasters, the results of the study can, likewise, aid policymakers in assessing the impact of disasters and thereby layout investment scenarios on the effect it might have.

STOCK MARKET AND NATURAL DISASTERS

The movements of the stock market have been examined in light of different factors including world events (Niederhoffer, 1971), calendar anomalies (Lakonishok & Smidt, 1988), non-economic events (Cutler, Poterba, & Summers, 1989), and the weather (Saunders, 1993), among others.

The effect of natural disasters on the stock market has captured the interest of researchers as early as 1990s. In two studies, Shelor, Anderson, and Cross (1990, 1992) found that the 1989 California earthquake can be viewed as unfavorable to real estate firms but, in contrast, beneficial on the stock price of insurance firms. The negative response of the stock prices on real estate firms was regarded as an indication of the unfavorable location of the properties. In contrast, the positive market response on the stock price of insurance firms was deemed likely due to investor expectations of higher demand for property-liability insurance-related products.

Lamb (1995), utilizing event study, examined the ability of the market to discriminate by the degree of loss exposure of property-liability insurers in response to the occurrence of Hurricane Andrew. The market was able to discriminate among firms relative to its geographic risk exposure. The negative impact of Hurricane Andrew was also confirmed in the study by Angbazo and Narayanan (1996).

Yamori and Kobayashi (1999) examined the “gaining from loss” hypothesis, which suggests that stock prices increase as a result of a disaster, that is, earthquake, in the context of Japanese insurers’ value. The results of the study indicate negative stock price reactions to the said catastrophic event unlike that of the United States for a similar event.

Worthington and Valadkhani (2004, 2005) examined impact of different natural disasters on the Australian equity market. Different sectors were found to have varying response to the form of disaster. In a more recent study, Worthington (2008), using the Generalized Autoregressive Conditional Heteroskedasticity-in-Mean (GARCH-M) model, found that natural disasters have no significant impact on the returns at the market level.

The "gaining from loss" hypothesis, in Shelor et al. (1992), implied that stock prices are positively influenced by disasters. The losses derived from disasters contribute to gains in some business sector. For instance, the stock prices of property-liability insurers were pushed upward as a result of an increase in the demand for insurance coverage following the 1989 destructive earthquake in California. On the opposing side, market returns, according to Worthington (2008), in general, are likely to be adversely affected by the occurrence of natural disasters. Intuitively, stock prices might not react to disasters.

Aquino (2006), in examining the statistical properties of PSE composite index (PSEi), found that the market seemingly ignored the Luzon earthquake in 1990 but took notice of the Mount Pinatubo eruption.

The recent devastation in Japan, brought about by the country's strongest earthquake to date and the subsequent tsunami and breakdown of nuclear reactor facility, provides an insight on the manner in which investors act in light of disasters. The earthquake evidently caused a downturn of stock markets not only in Japan but in different stock exchanges abroad including the Hong Kong and New Zealand market. Analysts, in various news articles, projected that the Japan earthquake will provide a good buying opportunity (Gentle, Gammeltoft, & Nazareth, 2011). Investors might see it fit to selectively buy cheap stocks that could benefit from the rebuilding efforts of the country.

Markets have demonstrated opposing response to incidents of disasters. The response of the market has been seen, in the extant literature, to vary depending on the index and the country being considered. Understanding the effect of natural disasters that occur in the Philippine context as exhibited in the behavior of the stock market prices is seen as a gap in the literature. Testing the "gaining from loss" hypothesis can contribute to uncovering how the country's stock market moves in response to natural disasters.

DATA AND METHODOLOGY

Studies examining the effect of natural disasters have displayed a particular tendency to utilize intervention analysis. This study will examine the behavior of the aggregate return using a variation of the generalized autoregressive conditional heteroskedasticity (GARCH) of Bollerslev (1986).

Two datasets required in the study include: i) the list of natural disasters; and ii) the closing price of the composite index. The list of natural disasters was obtained electronically from the Emergency Events Database (EM-DAT) of the Centre for Research (2011) on the Epidemiology of Disasters (CRED). According to EM-DAT, an event is considered a disaster when it meets at least one of the following criteria: i) 10 or more people are killed; ii) 100 or more people are affected; iii) a state of emergency is declared; or iv) a call for international assistance was made. Between 1985 and 2010, a total of 185 instances of natural disasters, translating to 616 days, were compiled from the EM-DAT.

The composite index, designated as the PSEi, is the main-share index of the Philippine market and is comprised of the biggest companies or top 30 corporations in the country. The list closing price of the index for the period 3 January 1985 to 30 December 2010 was obtained from the PSE archive and the country's leading newspapers.

The series for the daily market returns was obtained as the log of the ratio between the closing price for the day and the previous day. Following Worthington (2008), the GARCH(p,q)-M[1] model for examining the effect of the natural disasters can be described as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{n} \alpha_k (ND)_k + \beta_0 h_t + \varepsilon_t \qquad (1)$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{a} \beta_j \mathrm{h}_{t-j} \qquad (2)$$

$$\varepsilon_t \mid \Omega_{t-1} \sim \mathrm{N}(0, \mathrm{h_t}) \qquad (3)$$

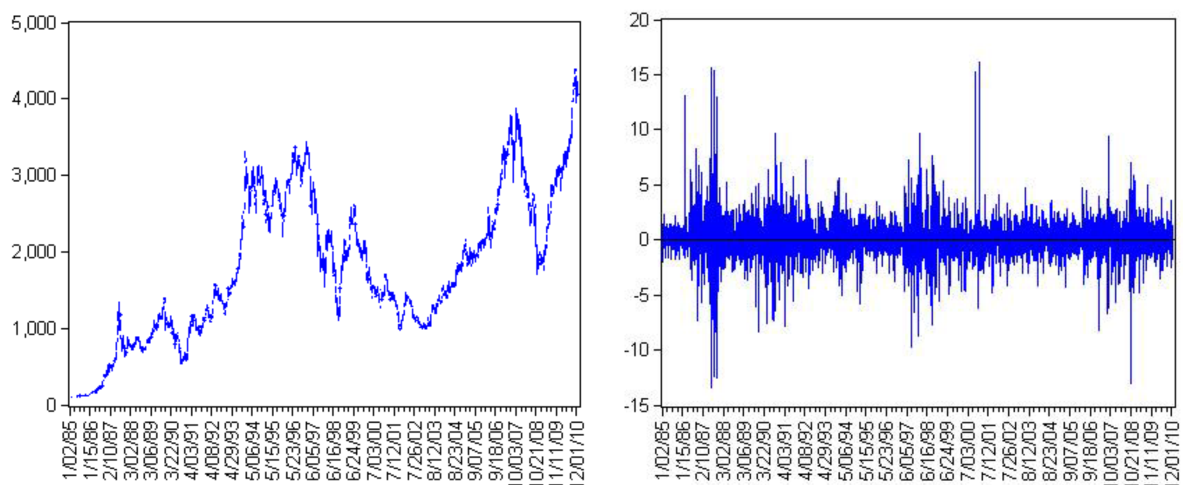
The R_t, or the market return at day t in Equation (1), is regarded as an agglomeration of the effect of natural disasters, risk, and a residual term. Equation (2) exhibits that the conditional variance is derived from the past behavior of the variance and the squares of past error term. The ε_t term, or error or residual term, is deemed normally distributed with zero mean and a variance of h_t.

Several studies, including those of Theodossiou and Lee (1995), Salman (2002), Brewer, Carson, Elyasiani, Mansur, and Scott (2007), and Worthington (2008), have demonstrated GARCH(1,1)-M to be sufficient for modeling the behavior of financial markets. Model selection, for this study, was however based on the values of the Akaike Information Criteria (AIC) and Schwarz Criterion (SC)[2].

RESULTS AND DISCUSSION

The daily closing price and returns of the PSEi from 1985 to 2010 are presented in Figure 1. The returns of the PSEi show volatility clustering, that is, property exhibiting periods of high and low variance.

Table 1 shows the descriptive statistics for assessing the daily market returns wherein the PSEi returns, for the period under consideration, is positively skewed (0.2252), leptokurtic (13.3669), and suggestive of non-normality. Positive skewness is indicative of positive outliers, that is, more frequent occurrence of positive extreme values. The returns' leptokurtic characteristic



Note: PSEi closing and returns for the period 2 January 1985 to 30 December 2012

Figure 1. *PSEi closing price and returns.*

Table 1.

Descriptive Statistics for Market Returns

	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	JB	Prob.
PSEi returns	0.0582	0.0328	16.1776	-13.3931	1.7130	0.2252	13.3669	28793.98	0.0000

Note: *6,419 obs. for PSEi closing price; 6,418 obs. for PSEi returns* demonstrates the tendency of the returns to have a low amount of variance, that is, returns group around the mean.

Table 2.

Unit Root Test (ADF) for Closing Price and Returns

Index	ADF a (Prob.)	
	Closing price	Returns
PSEi	-0.8975 (0.7897)	-53.8242 * (0.0000)

Note: *Unlike the series for the closing price, the index returns series is stationary;*

[a] Test critical values for ADF: -3.4312 at 1%, -2.8618 at 5%, and -2.5669 at 10%

* indicates significance at 1%; ** indicates significance at 5%; *** indicates significance at 10%

The Augmented Dickey-Fuller (ADF) test[3], in Table 2, indicates that the series on the closing price of the composite index is non-stationary while that of the index returns, on the other hand, is stationary. The behavior of the latter series allows regression to be employed to the said data.

The rejection of the no ARCH effect hypotheses, from the autocorrelation of squared PSEi returns[4] in Table 3, confirms the presence of volatility clustering that can be inferred visually from Figure 1. Such behavior is further indicative of a GARCH type specification. GARCH can be used for a series that exhibits non-normality and has an indication of ARCH behavior. Model estimation, based on the AIC and SC, suggested GARCH(2,2)-M to be the best fit for modeling the behavior of the returns on the period considered.

Table 3.

Autocorrelation of Squared Returns

	AC	Q-Stat	Prob
1	0.214	293.37	0.000
2	0.217	596.97	0.000
3	0.139	721.66	0.000
4	0.115	806.77	0.000
5	0.118	896.92	0.000
6	0.099	959.94	0.000
7	0.105	1030.6	0.000
8	0.120	1122.9	0.000
9	0.157	1280.5	0.000
10	0.100	1345.3	0.000
11	0.077	1383.8	0.000
12	0.092	1438.3	0.000
13	0.121	1531.7	0.000
14	0.125	1632.6	0.000
15	0.128	1738.5	0.000

Note: *ARCH effect is observed confirming the presence of volatility clustering*

Table 4.

GARCH(2,2)-M Estimates for PSEi Returns from 1985 to 2010

Parameter	Estimates
	Mean equation
GARCH	0.0201** (0.0092) [0.0285]
C	0.0050 (0.0209) [0.8103]
EARTHQUAKE	0.2802 (0.4069) [0.4911]
TROPICAL_ CYCLONE	0.0014 (0.0509) [0.9776]
VOLCANO	-0.1702 (0.1553) [0.2731]
	Variance equation
C	0.0017* (0.0006) [0.0087]
α1(1)	0.1749* (0.0156) [0.0000]
α1(2)	-0.1710* (0.0153) [0.0000]
β 2(1)	1.7401* (0.0253) [0.0000]
β 2(2)	-0.7445* (0.0243) [0.0000]
α + β	0.9995
	Remark
	Fairly specified

Notes: *Standard errors are given in parentheses; Prob. is in square brackets*

[1] RESID(-1)^2, the ARCH effect
[2] GARCH(-1), the GARCH effect
* indicates significance at 1%; ** indicates significance at 5%; *** indicates significance at 10%
: The results for the PSEi support the "gaining from loss" hypothesis wherein the occurrences of disasters, although statistically insignificant, likely contribute to increasing returns.
Volatility can also be seen to exert a positive and significant influence on returns.

From Table 4, the results for the PSEi support the "gaining from loss" hypothesis wherein the occurrences of disasters, although statistically insignificant, likely contribute to increasing returns. Volatility can also be seen to exert a positive and significant influence on returns. The coefficient of the ARCH term and GARCH term in the conditional variance equation suggest that the immediate past shock influences the market to a lesser extent compared to volatility shocks, that is, older news has more influence on the market. With the sum of the ARCH and GARCH term close to unity, volatility shocks can be deemed quite persistent.

Table 5.

Correlogram of Squared Residuals

	AC	Q-Stat	Prob
1	-0.005	0.1319	0.716
2	-0.005	0.2878	0.866
3	-0.002	0.3116	0.958
4	-0.008	0.6776	0.954
5	-0.002	0.7021	0.983
6	-0.006	0.9162	0.989
7	-0.007	1.2008	0.991
8	-0.005	1.3670	0.995
9	-0.004	1.4910	0.997
10	0.000	1.4912	0.999
11	-0.004	1.5779	1.000
12	-0.002	1.6016	1.000
13	-0.005	1.7795	1.000
14	-0.001	1.7855	1.000
15	-0.004	1.8655	1.000

Note: *ARCH effect is not observed on the residuals.*

Tables 5 and 6 indicate that the GARCH(2,2)-M model for the PSEi returns is fairly specified. No residual ARCH and remaining ARCH effects are confirmed in the correlogram of squared residuals[5] and ARCH LM test[6] for residuals respectively.

From Table 7, except for volcanic eruption, the difference between means on the non-occurrence and occurrence of earthquakes or tropical cyclones is statistically insignificant.

The behavior of the main-share index over the period 2 January 1985 to 30 December 2012 can be captured using the GARCH(2,2)-M model. The results for the PSEi returns demonstrate support for the "gaining from loss" hypothesis of Shelor et al. (1990) wherein the occurrences of disaster, that is, earthquakes and tropical cyclones, contribute to increasing market returns. The positive response of the Philippine market to

Table 6.

ARCH LM Test for Residuals

	LM(1)	LM(5)	LM(10)
F-statistic	0.1318 (0.7166)	0.1416 (0.9825)	0.1530 (0.9988)
Obs*R-squared	0.1318 (0.7166)	0.7087 (0.9825)	1.5324 (0.9988)

Note: *ARCH effect is not observed on the residuals.*

Table 7.

Summary of T-Test Results for PSEi Returns

	Earthquake	Tropical cyclone	Volcanic Eruption
Non-occurrence			
Mean	0.058	0.051	0.062
Std. dev	1.714	1.696	1.710
# of obs.	6409	5871	6358
Occurrence			
Mean	0.237	0.139	-0.320
Std. dev	0.562	1.881	1.991
# of obs.	9	547	60
***t*-statistic**	-0.314 (0.754)	-1.064 (0.288)	1.717 (0.086)***
#of obs.	6418	6418	6418

Note: ** indicates significance at 1% ** indicates significance at 5%*

**** indicates significance at 10%; A significant difference between the means of PSEi returns can be observed for volcanic eruptions only* natural disasters is seemingly consistent with the response of the aggregate index on the Australian stock market.

Further examination reveals that earthquakes and tropical cyclones, unlike volcanic eruptions, may pose a favorable increase of the PSEi returns. Perhaps, the companies listed under the PSEi are resilient to earthquakes. It is also possible that the earthquake lacked the magnitude to cause a systemic damage on the firms comprising the aforementioned index. The insignificant difference of means for tropical cyclones can be an indication that the location of the company's production facility as well as its distribution area is not adversely affected. The significant difference derived from volcanic eruptions is a resultant of the systemic untoward effect on the country's economy thereby triggering a lower return for the main-share index.

Although support for the "gaining from loss" hypothesis is evident, the effect of disasters on the PSEi returns, however, appears insignificant. Other factors, such as changes in the country's economic and political situations and changes affecting the global economy, are likely to emerge as more important in determining the returns of the composite index. The 1986 People Power Revolution, for example, catapulted the Philippine stock market among the best performing markets in the world during the aforementioned period (Sy, 2011).

CONCLUSIONS

The Philippines is endowed with the occurrences of natural disasters by virtue of its geography. Earthquakes, tropical cyclones and volcanic eruptions frequent the country's landscape. Of interest is explaining the movement of the composite index in light of the occurrences of disasters. In capsule, do such occurrences affect the stock market and to what extent?

Following Worthington (2008), the behavior of the main-share index from over the period 2 January 1985 to 30 December 2010 can be captured using the GARCH(2,2)-M model. The behavior of the PSEi suggests that disasters can be regarded, on occasions, as an unsystematic risk. In the context of the Philippine market, the composite index can be seen to support the "gaining from loss" hypothesis of Shelor et al. (1990) for earthquakes and tropical cyclones. An opposite behavior was observed for the occurrence of volcanic eruptions.

RECOMMENDATIONS

Succeeding researches are directed toward examining the market behavior using several alternative methodologies. Financial managers are directed to examine the behavior of individual firms comprising the main-share index to map specific response of firms. Mapping the behavior of firms can aid in decisions relating to portfolio management. Other stakeholders such as policymakers (investors) are encouraged to be aware of the extent disasters that affect market performance for them to make appropriate steps to ensure that the market (their portfolio) is resilient. In addition, policymakers can consider including market movements in assessing the impact of natural disasters.

Future work can also consider other events including technological disasters (EM-DAT, 2011) as well as disasters of human origin such as terrorism (Worthington et al., 2004). The effect of terrorism in the domestic setting and the spillover effect of incidents abroad on the financial market as well as sector- and firm-level response to the different natural disasters utilized in this study would be interesting.

ENDNOTES

1 The GARCH-M links the conditional variance and the conditional mean of returns providing a framework to examine relationship between market risk and expected returns. See Engle, Lilien, and Robins (1987) for a detailed discussion of the aforementioned framework.

2 The AIC and SC are used, in this study, to select the best model among the alternatives. The model having

the minimum AIC and SC was considered. See Akaike (1973) and Schwarz (1978) for further details of Akaike and Schwarz information criterion respectively.

3 The ADF, with a null hypothesis of unit root, measures the stationarity of time series data, which provides an indication on whether or not regression can be employed on the data (Tripathy, Gore, & Arora, n.d.). The rejection of the null hypothesis for the ADF suggests that the series is stationary.

4 The autocorrelation of squared returns is computed to confirm the presence of volatility clustering as well as the ARCH effect.

5 Correlogram of squared residuals is used to determine the presence of autocorrelation. The presence of ARCH effects on the outcome of the squared residuals, after estimation of the GARCH model, is an indication that the model is not fairly specified.

6 The ARCH Lagrange Multiplier (LM) test, in tandem with the autocorrelation of squared residuals, is used to further check the robustness of the GARCH model.

REFERENCES

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B.N. Petrov, & F. Csàki (Eds.), *2nd International Symposium on Information Theory* (pp. 267-281). Budapest: Akademiai Kiado.

Angbazo, L. A., & Narayanan, R. (1996). Catastrophic shocks in the property-liability insurance industry: Evidence on regulatory and contagion effects. *Journal of Risk and Insurance*, *63*(4), 619–637.

Aquino, R. Q. (2006). Efficiency of the Philippine stock market. *Applied Economics Letters*, *13,* 463–470.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics, 31*(3)*,* 307–327.

Brewer, E., Carson, J. M., Elyasiani, E., Mansur, I., & Scott, W. L. (2007). Interest rate risk and equity values of life insurance companies: A GARCH–M model. *Journal of Risk and Insurance*, *74*(2), 401–423.

Cao, M., & Wei, J. (2005). Stock market returns: A note on temperature anomaly. *Journal of Banking and Finance*, *29*(6)*,* 1559–1573.

Cutler, D. M., Poterba, J. M., & Summers, L. H. (1989). What moves stock prices? *Journal of Portfolio Management, 15*(3), 4–12.

Emergency Events Database [EM-DAT]. (2011). The OFDA/CRED international disaster database [Data file]. Retrieved from http://www.emdat.be/

Engle, R. F., Lilien, D. M., & Robins, R. P. (1987). Estimating time varying risk premia in the term structure: The ARCH-M model. *Econometrica, 55*(2), 391-407.

Gentle, N., Gammeltoft, N., & Nazareth, R. (2011, March 14). *Global stock rally may withstand earthquake, Japan share losses*. Retrieved April 4, 2011 from http://www.businessweek.com/news/2011-03-14/global-stock-rally-may-withstand-earthquake-japan-share-losses.html

Hirshleifer, D., & Shumway, T. (2003). Good day sunshine: Stock returns and the weather. *Journal of Finance, 58*(3), 1009-1032.

Lakonishok, J., & Smidt, S. (1988). Are seasonal anomalies real? A ninety-year perspective. *Review of Financial Studies, 1*(4), 403–425.

Lamb, R. P. (1995). An exposure-based analysis of property-liability insurer stock values around hurricane Andrew. *Journal of Risk and Insurance, 62*(1), 111–123.

National Disaster Coordinating Council (NDCC). (2009). *Strengthening disaster risk reduction in the Philippines: Strategic national action plan 2009-2019*. Philippines: NDCC.

Niederhoffer, V. (1971). The analysis of world events and stock prices. *Journal of Business, 44*(2), 193–219.

Salman, F. (2002). Risk-return-volume relationship in an emerging stock market. *Applied Economics Letters*, *9*(8), 549–552.

Saunders, E., Jr. (1993). Stock prices and Wall Street weather. *American Economic Review, 83*(5), 1337–1345.

Shelor, R. M., Anderson, D. C., & Cross, M. L. (1990). The impact of the California earthquake on real estate firms' stock value. *Journal of Real Estate Research, 5*(3), 335–340.

Shelor, R. M., Anderson, D. C., & Cross, M. L. (1992). Gaining from loss: Property-liability insurer stock values in the aftermath of the 1989 California earthquake. *Journal of Risk and Insurance*, *59*(3), 476–488.

Schwarz, G. (1978). Estimating the dimension of a model. *Annals of Statistics, 6*(2), 461–464.

Sy, V. (2011, February 28). People Power and the stock market. *The Philippine Star*. Retrieved September 17, 2011 from http://www.philstar.com/

Theodossiou, P., & Lee, U. (1995). Relationship between volatility and expected returns across international stock markets. *Journal of Business Finance and Accounting, 22*(2), 289–300.

Tripathy, N., Gore, A. P., & Arora, M. (n.d.) Trading volume, volatility and leverage: A dynamic analysis of the Indian stock market. Retrieved July 31, 2011 from http://www.wbiconpro.com

Valle-Sison, J. (2009, October 16). Natural disasters and the economy. *BusinessWorld*. Retrieved July 23, 2010 from http://www.bworld.com.ph/

Worthington, A.C. (2008). The impact of natural events and disasters on the Australian stock market: A GARCH-M analysis of storms, floods, cyclones, earthquakes and bushfires. *Global Business and Economics Review, 10*(1), 1–10.

Worthington, A.C., & Valadkhani, A. (2004). Measuring the impact of natural disasters on capital markets: An empirical application using intervention analysis. *Applied Economics, 36*(19), 2177–2186.

Worthington, A.C., & Valadkhani, A. (2005). Catastrophic shocks and capital markets: A comparative analysis by disaster and sector. *Global Economic Review, 34*(3), 331–344.

Yamori, N., & Kobayashi, T. (1999). *Is it true that insurers benefit from a catastrophic event? Market reactions to the 1995 Hanshin-Awaji earthquake* (Pacific Basin Working Paper No. 4). San Francisco, CA: Center for Pacific Basin Monetary and Economic Studies, Federal Reserve Bank of San Francisco.