



Connectivity in Global Stock Markets during Financial Crisis

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Abstract

This study analyzes the co-movement and causality of continental and intercontinental stock prices during the times of financial crisis. The co-movement of stock price-earnings ratios in each continent is analyzed and significant increase in co-movement during the times of financial crisis is verified. In addition, time-series data are analyzed by the following methods: unit root time series, co-integration, vector autoregressive (VAR) model, impulse response, forecast error variance decomposition, and Granger causality. The results show a significant increase in Granger causality of intercontinental price-earnings ratios during the times of financial crisis. An intercontinental path of impulse transfer is also identified during financial crises. These analyses can assist in controlling the risks of the international crises and help investors design effective investment strategies.

Key words: financial crisis, global stock market, comovement, Granger causality, vector autoregressive model, impulse response

1. INTRODUCTION

With the increasing size and complexity of the global stock market, domestic and international stock markets are becoming increasingly interconnected. Global financial markets have opened and various means of investment have developed, enabling easier inflow and outflow of capital, which has led to increased volume and foreign transactions and global liquidity. Madaleno & Pinho (2012) argued

that stock market indexes have been changed by the various financial crises that have occurred and that stock markets that are closely related geographically and economically are likely to exhibit comovement. Stock markets of various countries have been increasingly affected by international stock prices, interest rates, and exchange rates, and comovement of financial markets in general has increased.

The reinforced interconnectedness of financial

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markets has resulted in improved efficiency of financial markets and systems but it has also caused many problems. Due to the increased interdependence of financial markets, a country's risk formed during a crisis is more likely to spread to other countries and become a global phenomenon. As financial markets are becoming increasingly complex, their volatility and uncertainty are increasing. Financial systems are vulnerable to such financial risks. In fact, the world experienced the ripple effect of unstable financial markets and risks during incidents such as the Asian financial crisis of 1997, the Long-Term Capital Management L.P. (LTCM) crisis of 1998, the 9/11 terrorist attack on the United States, and the global financial crisis of 2007. Bekaert, *et. al.* (2014) found that the 2007-2009 financial crisis greatly affected the stock markets of many countries, as well as the investment portfolios of individuals.¹⁾

Therefore, it is important for countries and individual investors to have a thorough understanding of global financial markets and their connections in order to prevent losses due to financial crisis. For this reason, this study examines financial markets by analyzing comovement of continental stock prices and Granger causality of intercontinental stock prices.

The contributions of this study are as follows. First, Granger causality of stock prices and comovement before financial crisis, during stable periods, and after financial crisis are analyzed with a focus on

ripple effects. Second, the spreading of risk from a specific country or continent to other continents during financial crisis is illustrated.

In the analyses, for each continent, log price-earnings ratios based on weekly stock market indices for 1996-2013 for representative countries are gathered and averaged by use of a market-value-weighted approach. Kendall's tau and Spearman's rho are used in order to analyze continental stock price comovement, especially during periods of financial crisis. In addition, time series analysis of the intercontinental relationships among stock prices is performed by use of the following methods: unit root test, cointegration, vector autoregressive (VAR) model, impulse response, and forecast error variance decomposition (FEVD). The hypothesis is tested using regression equations for Granger causality.

The structure of this paper is as follows. Section 1 serves as an introduction. Section 2 presents the research methodology for analyzing comovement and Granger causality. Section 3 reports the results of the empirical analysis. Finally, section 4 presents the conclusions.

II. RESEARCH METHODOLOGY

1. Data

Weekly log price-earnings ratios are used in this paper to verify comovement of continental price-earnings ratio and Granger causality of

1) Billio, *et. al.* (2012) examined systemic risk of hedge funds, mutual funds, insurance companies, and banks by use of principal component analysis and the Granger causality test, showing that principal risk components increase and mutual Granger causality strengthens when a financial crisis occurs. Cheng & Glascock (2006) performed principal component analysis and Granger causality analysis to estimate the interconnectedness between the U.S. stock market and Asian stock markets (with China, Hong Kong, and Taiwan serving as representative Asian stock markets) before and after the Asian financial crisis. They showed that the relationships between stocks markets were reinforced by the Asian financial crisis.

intercontinental price-earnings ratios. Weighted-average price-earnings ratios for each continent—Asia, Europe, the Middle East, Africa, South America, and North America—are calculated based on the market values of countries in that continent. The representative countries chosen for each continent are as follows: four countries (Jordan, Oman, Qatar, and Saudi Arabia) for the Middle East; four countries (Egypt, Mauritius, Morocco, and South Africa) for Africa; eleven countries (Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, Philippines, South Korea, Taiwan, and Thailand) for Asia; nine countries (Denmark, Norway, Spain, Switzerland, the United Kingdom, Belgium, France, Germany, and the Netherlands) for Europe; three countries (Canada, Mexico, and the United States) for North America; and four countries (Argentina, Brazil, Chile, and Venezuela) for South America.

The source data are weekly stock market indexes for January 1996 through April 2014 and are obtained from Bloomberg; due to data unavailability, data for the Middle East are for only January 2000 through April 2014 and data for Africa are for only July 1998 through April 2014.

For the Granger causality analyses, the period 1996–2013 is divided into seven subperiods, each classified as either financial crisis or stable. The subperiods are as follows: the stable period of 1996, the Asian financial crisis of 1997–1999, the period 2000–2001, which brackets the 9/11 terrorist attack on the United States, the War in Iraq and the intervention of the U.S. federal government in the U.S. financial markets during 2002–2004, the relatively stable period in 2005–2006, the global financial crisis of 2007–2009, and

the European financial crisis and rise of international oil prices in 2010–2013. Granger causality analysis is performed for each of the seven periods.

2. Analysis of Continental stock Price Comovement

One of the primary concepts in this study is concordance. Concordance refers to consistent movement among variables. Spearman's rho (ρ) and Kendall's tau (τ) are widely used measurements of rank correlation. First, Scarsini (1984) introduced axioms for the measurement of concordance between two variables. Later, Taylor (2007) demonstrated that the expansion of Scarsini's axioms from bivariate to multivariate. In addition, Dolati & Ubeda-Flores (2006) and Schmid & Schmidt (2007a, 2007b) found that both Spearman's rho and Kendall's tau satisfy Taylor (2007)'s expanded axioms (for additional information, see Rodriguez, 2007; Kendall, 1990). Both correlation coefficients are proven measurements of multivariate concordance. Accordingly, this study uses Spearman's rho and Kendall's tau to estimate the comovement of price-earnings ratios within each continent.

Spearman's rho and Kendall's tau may not provide the same estimated correlation for two variables (Fredrics & Nelson, 2007). A large value of Spearman's rho does not always indicate a large value of Kendall's tau, and vice versa. In other words, rank correlations measured by Spearman's rho can differ from rank correlations measured by Kendall's tau, and using the two methods together at the same time can lead to confusion in interpretation. Spearman's rho and Kendall's tau both have advantages and disadvantages. Rho is simpler to calculate than is tau. However, because

the distribution of tau converges to a normal distribution faster than does the distribution of rho, a normal approximation can yield a more accurate estimate of tau than of rho (Xu, *et. al.*, 2013). Regardless, even if values of tau and rho differ during the independence test, the conclusion to reject or accept the hypothesis is generally the same. Neither simplicity of calculation nor normal approximation should be regarded as grounds for selecting one method over the other. In measuring multivariate concordance, Spearman's rho, Kendall's tau, pair wise Spearman's rho, and pair wise Kendall's tau all exhibit high efficiency (Joe, 1990).

Thus, both Spearman's rho and Kendall's tau are used in this study for the relative comparison of comovement of price-earnings ratios. Instead of relying on the accuracy of one of the correlation coefficients for interpretation, this study interprets both measurements showing a high correlation as being indicative of greater reliability than results for which only one measurement shows a high correlation.

3. Analysis of Intercontinental Granger Causality

1) Dickey-Fuller (D-F) Test

To determine the appropriate model for analyzing a time series, it is necessary first to determine whether the given time series is normally distributed. In other words, the priority must be placed on the Dickey-Fuller test (Sheng & Tu, 2000) to check, based on unit root, whether the given time series is normally distributed.

When a time series that follows a p-th autoregressive process is assumed, the following equation can be obtained:

$$x_t = a_0 + a_1x_{t-1} + a_2x_{t-2} + \dots + a_px_{t-p} + \epsilon_t \quad (1)$$

Equation (1) can be transformed into the following equation, which expresses the change in variable over time as $\Delta x_t = x_t - x_{t-1}$:

$$\Delta x_t = a_0 + a_1x_{t-1} + a_2x_{t-2} + \dots + a_px_{t-p} + \epsilon_t \quad (2)$$

in which

$$r = \left[1 - \sum_{t=1}^p a_t \right] \quad \text{and} \quad \beta = \sum_{j=t}^p a_t \quad (3)$$

In Equation (2), the null hypothesis is that. When this hypothesis is true, is said to have a unit root.

2) Cointegration

Cointegration is a method of determining the long-term balance between individual vector time series. According to Sheng & Tu (2000), the Johansen cointegration model can be expressed as follows:

$$X_t = A_0 + A_1X_{t-1} + \epsilon_t \quad (4)$$

$$\Delta X_t = A_0 + \Pi X_{t-1} + \epsilon_t, \quad \Pi = A_1 - I \quad (5)$$

in which Equation (5) provides the rank of matrix Π . If $rank(\Pi) = 0$, cointegration does not exist. In that case, because there is no linear association among x_t variables, the time series is considered stable. In contrast, if $rank(\Pi) \neq 0$, cointegration exists, and the time series is considered unstable. It is then desirable to analyze the time series using the error-correction model.

3) Vector Autoregressive (VAR) Analysis

A VAR model of multivariate time series explains that a time series is affected not only by its present and past values but also by present and past values of other time series. Chevallier (2010) defined the p-th VAR model, or VAR(p), as follows when $Z_t = \begin{pmatrix} X_t^1 \\ X_t^2 \end{pmatrix}$ is a bivariate vector model:

$$Z_t = C + \Gamma_1 Z_{t-1} + \dots + \Gamma_p Z_{t-p} + \epsilon_t \quad (6)$$

in which $C = \begin{pmatrix} C^1 \\ C^2 \end{pmatrix}$ is a vector of constants, $\Gamma_1, \dots, \Gamma_p$ are 2×2 matrices, and the error term $\epsilon_t = \begin{pmatrix} \epsilon_t^1 \\ \epsilon_t^2 \end{pmatrix}$ is independent and identically distributed and follows $N(0, \Sigma)$.

4) Impulse Response Function (IRF)

If the time series is $\{X_t\} \sim VAR(p)$, then $X_t = \mu + e_t + \phi_1 e_{t-1} + \phi_2 e_{t-2} + \dots$ can be expressed as $VMA(\infty, \phi)$. The $VAR(p)$ model can be developed as follows, assuming that it takes X_1 and X_2 as variables:

$$\begin{bmatrix} X_{1t} \\ X_{2t} \end{bmatrix} = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} + \begin{bmatrix} \phi_{11}^{(1)} & \phi_{12}^{(1)} \\ \phi_{21}^{(1)} & \phi_{22}^{(1)} \end{bmatrix} \begin{bmatrix} e_{1,t-1} \\ e_{2,t-1} \end{bmatrix} + \begin{bmatrix} \phi_{11}^{(2)} & \phi_{12}^{(2)} \\ \phi_{21}^{(2)} & \phi_{22}^{(2)} \end{bmatrix} \begin{bmatrix} e_{1,t-2} \\ e_{2,t-2} \end{bmatrix} + \dots \quad (7)$$

in which, and the (i, j) element of , can be expressed as the following:

$$\phi_{i,j}^{(2)} = \frac{\partial X_{i,t+s}}{\partial X_{j,t}} = \frac{\partial X_{i,t}}{\partial X_{j,t-s}} \quad (8)$$

When $\phi_{i,j}^{(2)}$ is expressed as a function of s, it is referred to as an impulse response function (IRF).

5) Forecast Error Variance Decomposition (FEVD)

According to Sheng & Tu (2000), the VAR model can be rewritten, using vector moving-average method, as follows:

$$X = \mu + \sum_{j=0}^{\infty} A_t^j \gamma \epsilon_{t-j}$$

This equation can then be used to estimate the forecast error for period n as follows:

$$X_{t+n} - E_t X_{t+n} = \sum_{j=0}^{n-1} A \epsilon_{t+n-j} \quad (9)$$

in which the forecast error for is the following:

$$\sigma_1(n)^2 = \sigma_1^2 \sum_{j=1}^{n-1} a_{1,1}(j)^2 + \dots + \sigma_n^2 \sum_{j=1}^{n-1} a_{1,n}(j)^2$$

in which $A\gamma = [a_{\phi pq}(j)]_{n \times n}$ and $VAR(\epsilon_{tt}) = \sigma_t^2$. That is, the ratio of FEVD is as follows:

$$W_1(j) = \sigma_1^2 \sum_{j=1}^{n-1} \frac{a_{1,t}(j)^2}{\sigma_1(n)^2} \quad (10)$$

6) Granger Causality Test

The Granger causality test is a statistical test used for determining causality. It uses a lagged distributed model, a model defined by explanatory variables that include observed values of the present and past. The null hypothesis of the test is that x does not Granger-cause. According to Sheng & Tu (2000), the regression model for the test is as follows:

$$X_{t+1}^A = \gamma_o + \sum_{i=1}^P \alpha_i X_{t-1}^B + \sum_{j=1}^P \beta_j X_{t-j}^A + \epsilon_t \quad (11)$$

In this equation, Granger causality is rejected if the null hypothesis is true.

III. RESULTS OF EMPIRICAL ANALYSIS

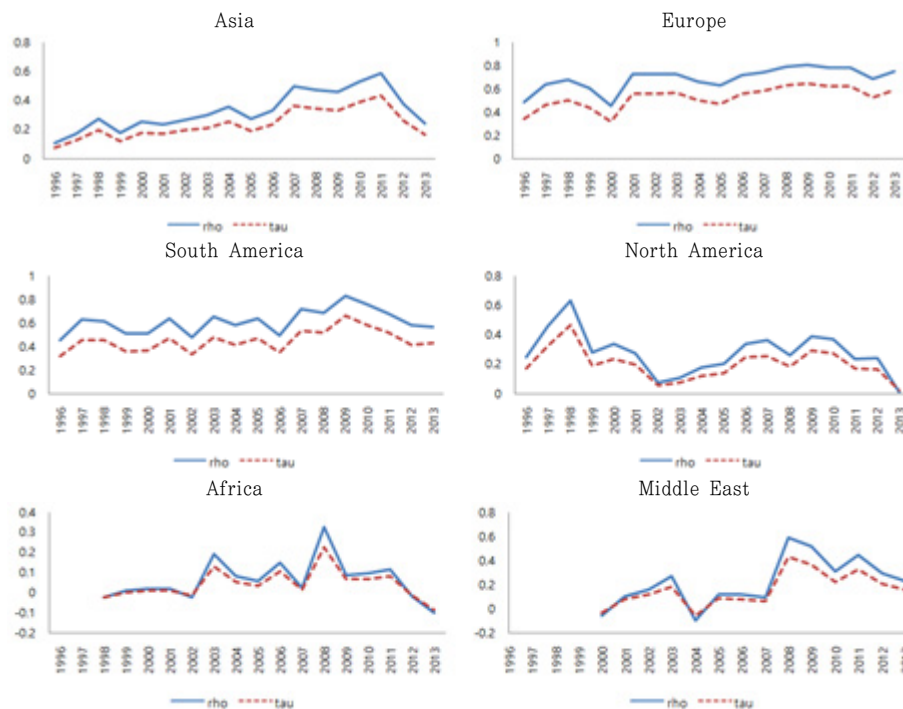
1. Results of Analysis of the Comovement of Continental Stock Price–Earnings Ratios

The graphs below show the results of analyzing the comovement of stock price–earnings ratios in each continent, using both Spearman’s rho and Kendall’s tau.

First, looking at the comovement graph for price–earnings ratios in Asia, high comovement occurred in 1997 during the Asian financial crisis and again in 1998 when the Russian default happened. Comovement strengthened more dramatically with the 2007–2008 global financial crisis and the European financial crisis of 2011.

In the case of Europe, comovement was very strong during the entire period 1996–2013 except for 1999 and 2000. This strong correlation of stock prices among European countries seems to be the result of the euro currency being introduced by the European Union. Comovement also strengthened in Europe during the financial crisis of 2007 and the European financial crisis of 2011.

In North America, comovement of price–earnings ratios strengthened during the Asian financial crisis of 1997 and the 9/11 terrorist attack in 2001. The outbreak of the Enron scandal in 2002 led to contraction of U.S. financial markets, and the U.S. Federal Reserve Board intervened in the market by increasing the key interest rate, the federal funds rate. Comovement increased during this period of the Federal Reserve’s quantitative easing policy, and the correlation of stock prices



*Notes: The rank correlations shown are for weighted–average price–earnings ratios in which the weights are based on market value in the representative countries for each continent.

※ Source: Weekly stock market data from Bloomberg.

Figure 1. Comovement of price-earnings ratios in each continent, january 1996–april 2014

among countries in North America increased during the financial crisis of 2007–2008, as it did on other continents. The correlation of stock prices also increased during the European financial crisis of 2011.

The results for South America show increases in comovement of stock prices with the Asian financial crisis of 1997, the 9/11 terrorist attack on the United States in 2001, and the global financial crisis of 2007–2008.

Africa's comovement of price–earnings ratios also was strengthened by the financial crisis of 2007–2008.

In the Middle East, high comovement was shown between 2001 and 2003 due to the 9/11 terrorist attack on the United States in 2001 and the War in Iraq led by the allied forces of the United States and the United Kingdom in 2003.

Comovement increased again with the financial crisis of 2007–2008 and the European financial crisis of 2011.

2. Analysis of Intercontinental Influence

To examine Granger causality, it is necessary to determine whether the time series data for intercontinental price–earnings ratios are stable and whether there exists a long–term balance relationship. Therefore, this study tests for this by use of unit root tests and cointegration tests, analyzing the results in the order of VAR, impulse response, FEVD, and Granger causality. In addition, data from 1998–2013 are divided into seven subperiods in order to compare periods of financial crisis with stable periods. <Table 1>, <Table 2>, and <Table 3> report the results for the subperiod 2007–2009, when the global financial

Table 1. Augmented Dickey-Fuller unit root test results, 2007–2009

Continent	Type	Rho	Pr< Rho	Tau	Pr< Tau
Asia	Zero Mean	-119.46	0.0001	-7.67	<.0001
	Single Mean	-119.49	0.0001	-7.65	<.0001
	Trend	-119.54	0.0001	-7.63	<.0001
Europe	Zero Mean	-132.30	0.0001	-8.07	<.0001
	Single Mean	-133.14	0.0001	-8.07	<.0001
	Trend	-133.80	0.0001	-8.07	<.0001
North America	Zero Mean	-130.82	0.0001	-8.03	<.0001
	Single Mean	-131.24	0.0001	-8.02	<.0001
	Trend	-131.62	0.0001	-8.01	<.0001
South America	Zero Mean	-139.48	0.0001	-8.30	<.0001
	Single Mean	-141.05	0.0001	-8.32	<.0001
	Trend	-141.21	0.0001	-8.29	<.0001
Africa	Zero Mean	-136.84	0.0001	-8.22	<.0001
	Single Mean	-136.97	0.0001	-8.19	<.0001
	Trend	-137.00	0.0001	-8.17	<.0001
Middle East	Zero Mean	-153.24	0.0001	-8.70	<.0001
	Single Mean	-153.51	0.0001	-8.67	<.0001
	Trend	-153.95	0.0001	-8.66	<.0001

*Notes: The test statistics shown are for weighted–average price–earnings ratios in which the weights are based on market value in the representative countries for each continent.

※ Source: Weekly stock market data from Bloomberg.

crisis occurred. The results tables for the other subperiods have been omitted, because all subperiods have been tested for the hypothesis by use of the same method.

1) Unit Root Test

〈Table 1〉 reports the augmented Dickey-Fuller (ADF) unit root test results for the time series of intercontinental price-earnings ratios for 2007-2009.

$Pr(\rho)$ is 0.0001, and $Pr(\tau)$ is 0.0001. These results reject the null hypothesis that there is a unit root of the time series for price-earnings ratios for each continent. Thus, all time series are verified as stable time series without unit root.

2) Cointegration

〈Table 2〉 reports the statistical results obtained from the Johansen cointegration tests. Because these tests reject the null hypothesis that rank = r , it is apparent that there is no cointegration vector. Therefore, a long-term balance relationship

can be found in these time series data. A vector error correction model is used when the cointegration test result demonstrates that cointegration exists, and a VAR model is used when cointegration does not exist. Therefore, because the time series in this study do not exhibit cointegration, a VAR model is used to analyze the results.

3) VAR Analysis

〈Table 3〉 reports the results of analyzing price-earnings ratios of each continent using a VAR model. To estimate this model, the corrected Akaike information criterion (AICc) is defined to have the smallest value of $p=1$. The results show that the continents are mutually influenced at time $t-1$. In the VAR model, the value of time $t-1$ is estimated as shown in 〈Table 3〉. Based on the t -statistics, Asia's price-earnings ratio was affected by the lagged price-earnings ratio of North America, and Europe's price-earnings ratio was affected by the lagged price-earnings ratio of Africa, North

Table 2. Johansen cointegration test results

Test using trace				
H0: Rank = r	H1: Rank > r	Eigen value	Trace	5% Critical Value
0	0	0.7438	886.3833	93.92
1	1	0.7089	675.2855	68.68
2	2	0.6792	484.0141	47.21
3	3	0.5164	307.7800	29.38
4	4	0.5086	195.1747	15.34
5	5	0.4223	85.0424	3.84
Test using trace under restriction				
H0: Rank = r	H1: Rank > r	Eigen value	Trace	5% Critical Value
0	0	0.7438	886.3881	101.84
1	1	0.7089	675.2902	75.74
2	2	0.6792	484.0180	53.42
3	3	0.5164	307.7838	34.80
4	4	0.5086	195.1758	19.99
5	5	0.4223	85.0433	9.13

*Notes: Same as in 〈Table 1〉

※ Source: Weekly stock market data from Bloomberg.

Table 3. Vector autoregressive (VAR) model estimation results

Continent	Variable	Coefficient	Standard Error	t statistic	Pr> t
Asia	1	-0.00009	0.0011	-0.08	0.9379
	Asia _{t-1}	-0.04452	0.11528	-0.39	0.6999
	Europe _{t-1}	-0.34975	0.19351	-1.81	0.0727
	NorthAmerica _{t-1}	0.57857	0.18464	3.13	0.0021***
	SouthAmerica _{t-1}	-0.071	0.13768	-0.52	0.6069
	Africa _{t-1}	0.18699	0.13973	1.34	0.1829
	MiddleEast _{t-1}	-0.03361	0.06535	-0.51	0.6078
Europe	1	-0.00074	0.00122	-0.61	0.5447
	Asia _{t-1}	0.06676	0.12863	0.52	0.6046
	Europe _{t-1}	-1.17636	0.21592	-5.45	0.0001***
	NorthAmerica _{t-1}	1.17844	0.20602	5.72	0.0001***
	SouthAmerica _{t-1}	-0.23241	0.15363	-1.51	0.1325
	Africa _{t-1}	0.39034	0.15591	2.5	0.0134**
	MiddleEast _{t-1}	0.00808	0.07292	0.11	0.912
North America	1	-0.00046	0.00109	-0.42	0.673
	Asia _{t-1}	0.03535	0.11474	0.31	0.7585
	Europe _{t-1}	-0.86044	0.1926	-4.47	0.0001***
	NorthAmerica _{t-1}	0.80113	0.18377	4.36	0.0001***
	SouthAmerica _{t-1}	-0.32346	0.13704	-2.36	0.0196**
	Africa _{t-1}	0.55246	0.13907	3.97	0.0001
	MiddleEast _{t-1}	-0.03672	0.06504	-0.56	0.5733
South America	1	0.0014	0.00149	0.94	0.3496
	Asia _{t-1}	0.13313	0.15688	0.85	0.3975
	Europe _{t-1}	-0.77504	0.26333	-2.94	0.0038***
	NorthAmerica _{t-1}	0.89703	0.25126	3.57	0.0005***
	SouthAmerica _{t-1}	-0.45659	0.18736	-2.44	0.016**
	Africa _{t-1}	0.47473	0.19015	2.5	0.0136**
	MiddleEast _{t-1}	-0.0494	0.08893	-0.56	0.5794
Africa	1	0.00046	0.00111	0.41	0.683
	Asia _{t-1}	0.11515	0.1169	0.99	0.3262
	Europe _{t-1}	-0.63642	0.19621	-3.24	0.0015***
	NorthAmerica _{t-1}	0.80563	0.18722	4.3	0.0001***
	SouthAmerica _{t-1}	-0.19669	0.13961	-1.41	0.161
	Africa _{t-1}	0.04212	0.14168	0.3	0.7667
	MiddleEast _{t-1}	0.00501	0.06626	0.08	0.9398
Middle East	1	-0.00112	0.00138	-0.81	0.4181
	Asia _{t-1}	-0.05057	0.14449	-0.35	0.7269
	Europe _{t-1}	-0.96892	0.24253	-4	0.0001***
	NorthAmerica _{t-1}	0.81926	0.23142	3.54	0.0005***
	SouthAmerica _{t-1}	0.27214	0.17256	1.58	0.1169
	Africa _{t-1}	0.4603	0.17513	2.63	0.0095***
	MiddleEast _{t-1}	0.00457	0.08191	0.06	0.9556

*Notes: ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

※ Source: Weekly stock market data from Bloomberg

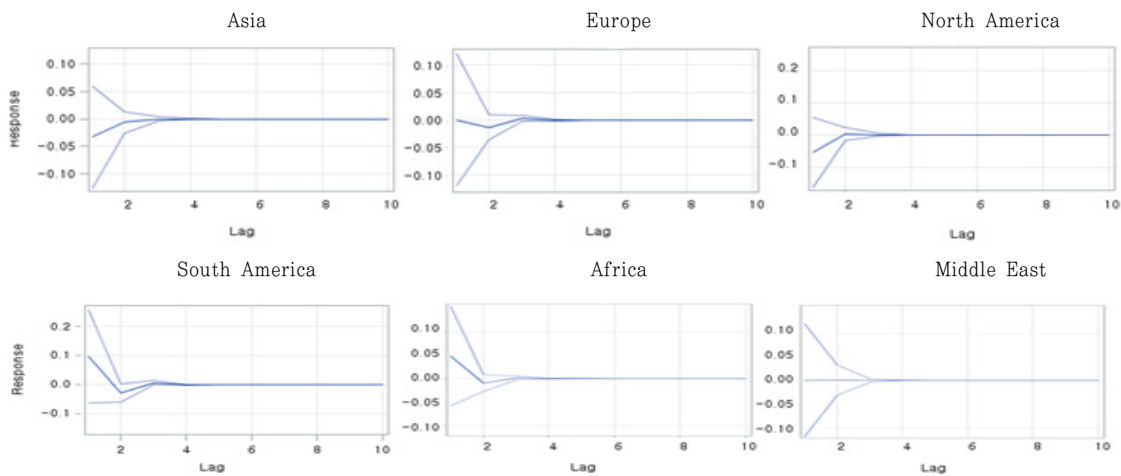
America's price-earnings ratio was affected by the lagged price-earnings ratio of South America, and South America's price-earnings ratio was affected by the lagged price-earnings ratios of North America and Europe. In addition, Africa's price-earnings ratio was affected by the lagged price-earnings ratios of Europe and North America, and the Middle East's price-earnings ratio was affected by the lagged price-earnings ratios of Europe, North America, and Africa.

4) Impulse Response Function (IRF)

The impulse functions are based on weighted-

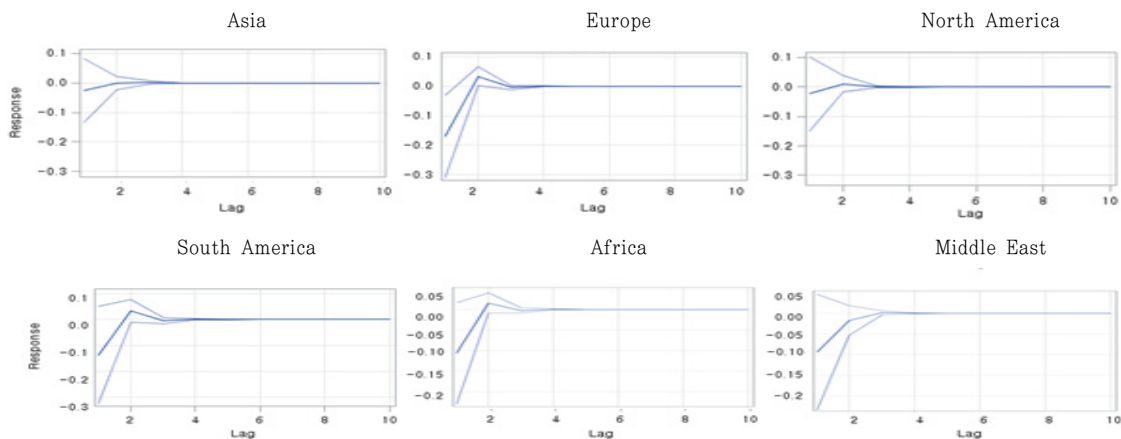
average price-earnings ratios in which the weights are based on market value in the representative countries for each continent. (Figure 2) through (Figure 7) show the impulse response functions that describe how other continents' price-earnings ratios respond, over time, to an impulse in another continent. For example, (Figure 2) shows other continents' responses to an impulse in Asia.

An impulse in Asia was found to immediately affect price-earnings ratios in all continents except the Middle East; in Europe, South America, and Africa, the effects persisted for three weeks, in Asia and North America, the effects lasted for



※ Source: Weekly stock market data from Bloomberg.

Figure 2. IRFs: other continents' responses to an impulse in Asia, with two standard errors



※ Source: Weekly stock market data from Bloomberg.

Figure 3. IRFs: other continents' responses to an impulse in Europe, with two standard errors

two weeks.

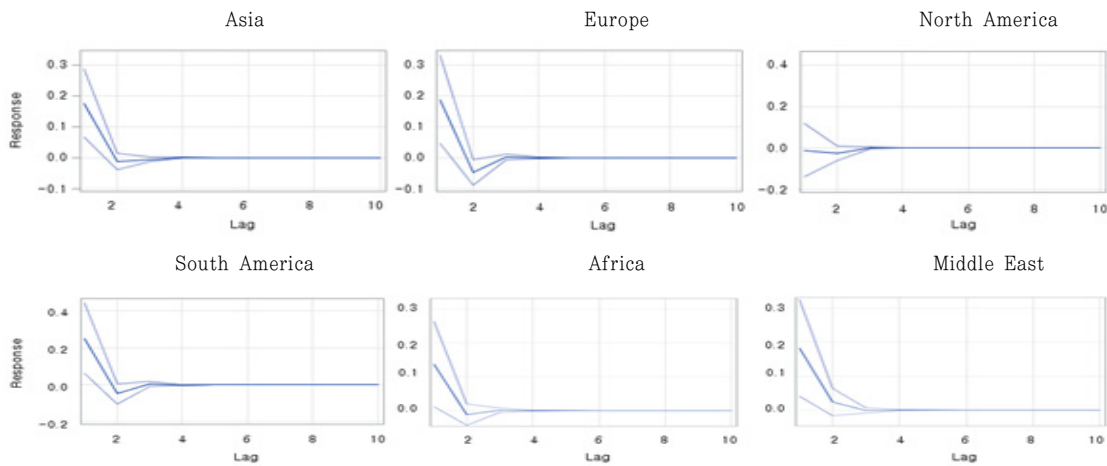
An impulse in Europe immediately affected price-earnings ratios in all continents. The effects lasted three weeks in Europe, South America, Africa, and the Middle East and lasted two weeks in Asia and North America.

An impulse in North America immediately affected price-earnings ratios in all continents, and the effects persisted for three weeks. As with an impulse in North America, an impulse in South America immediately affected price-earnings ratios in all continents, and the effects persisted

for three weeks.

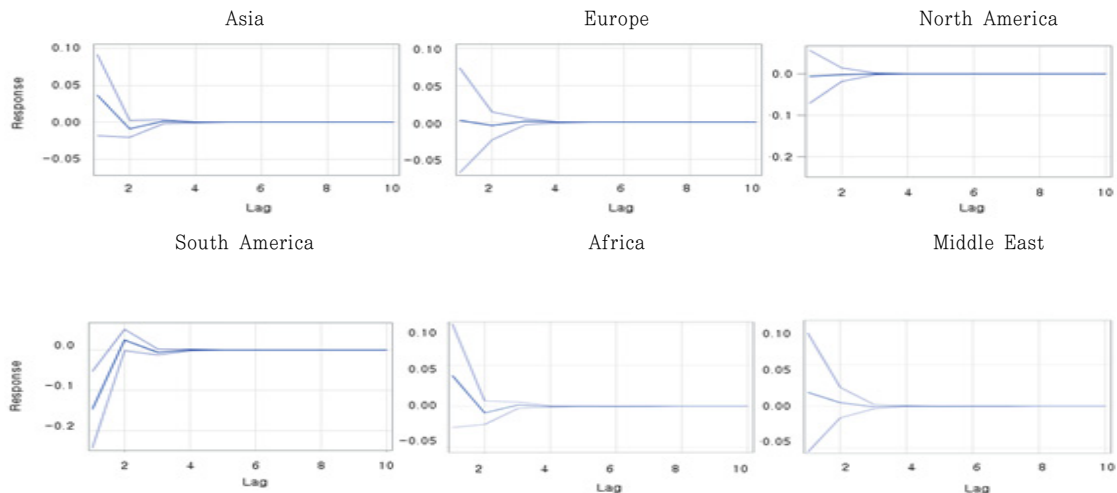
An impulse in Africa affected price-earnings ratios in Africa, Asia, Europe, and North America for three weeks and price-earnings ratios in South America and the Middle East for two weeks.

An impulse in the Middle East affected price-earnings ratios in all continents. The effects persisted for three weeks in Asia, Europe, South America, and Africa and for two weeks in North American and the Middle East.



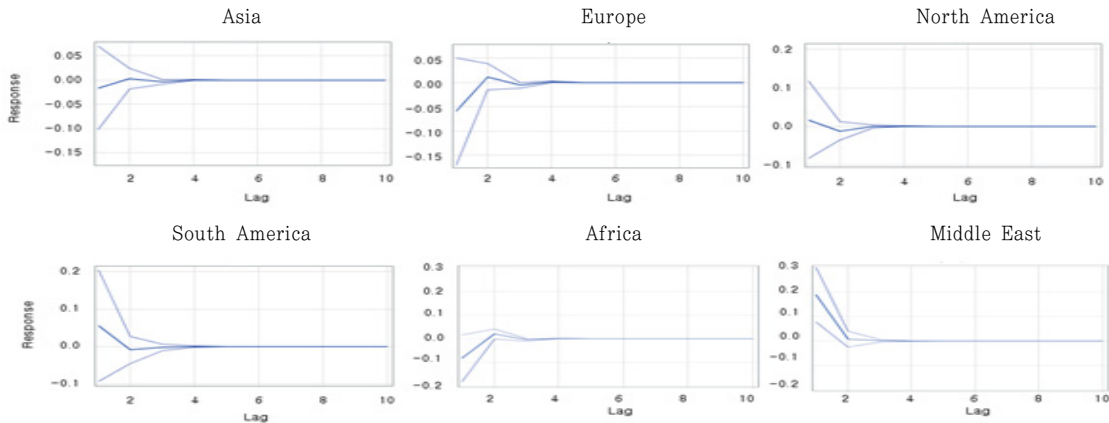
※ Source: Weekly stock market data from Bloomberg.

Figure 4. IRFs: other continents' responses to an impulse in North America, with two standard errors



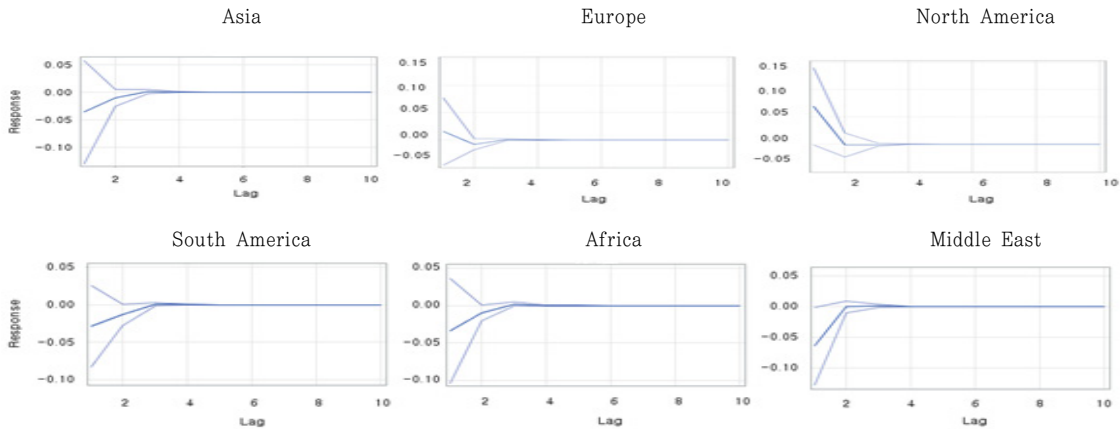
※ Source: Weekly stock market data from Bloomberg.

Figure 5. IRFs: other continents' responses to an impulse in South America, with two standard errors



※ Source: Weekly stock market data from Bloomberg.

Figure 6. IRFs: Other continents' responses to an impulse in Africa, with two standard errors



※ Source: Weekly stock market data from Bloomberg.

Figure 7. IRFs: other continents' responses to an impulse in the Middle East, with two standard errors

5) Forecast Error Variance Decomposition (FEVD) (Table 4) reports the results of FEVD. Changes in price-earnings ratios in Asia explain the following proportions of price-earnings ratio changes by continent: 1.2%-1.4% of Europe, 5.8% of North America, 0.12% of South America, 1.1%-1.7% of Africa, and 0.14%-0.17% of the Middle East. Changes in price-earnings ratios in Europe explain the following proportions of price-earnings ratio changes: 38%-48% of Asia, 15% of North America, 0.14%-0.17% of South America, 3.2%-3.7% of Africa, and 0.005%-0.17% of the Middle East. Changes in price-earnings ratios in North America explain the following proportions of

price-earnings ratio changes: 32.9%-39.8% of Asia, 33.7%-39.8% of Europe, 0.22%-0.29% of South America, 8.3%-8.4% of Africa, and 0.15%-0.2% of the Middle East. Changes in price-earnings ratios in South America explain the following proportions of price-earnings ratio changes: 47.4%-53.4% of Asia, 21.5%-22.9% of Europe, 0.92%-6.5% of North America, 3.6% of Africa, and 0.15%-0.18% of the Middle East. Changes in price-earnings ratios of Africa explain the following proportions of price-earnings ratio changes: 33.3%-38.2% of Asia, 19.3%-20.9% of Europe, 0.23%-10.19% of North America, 8.43%-8.51% of South America, and 0.003%-0.11% of the

Table 4. Forecast error variance decomposition (FEVD) results

Proportion of Prediction Error Covariances by Variable							
Continent	Lead	Asia	Europe	North America	South America	Africa	Middle East
Asia	1	1	0	0	0	0	0
	2	0.91788	0.01199	0.05771	0.00007	0.011	0.00136
	3	0.9094	0.01386	0.05747	0.00119	0.01635	0.00173
	4	0.90833	0.01388	0.05782	0.0012	0.01704	0.00173
	5	0.90831	0.01388	0.05783	0.00122	0.01703	0.00174
	6	0.9083	0.01388	0.05783	0.00122	0.01704	0.00174
	7	0.9083	0.01388	0.05783	0.00122	0.01704	0.00174
Europe	1	0.48106	0.51894	0	0	0	0
	2	0.38804	0.43227	0.14623	0.00137	0.03204	0.00005
	3	0.38209	0.42565	0.15488	0.00148	0.03448	0.00143
	4	0.38071	0.4242	0.15484	0.00156	0.03701	0.00169
	5	0.38049	0.42399	0.15482	0.00164	0.03736	0.0017
	6	0.38046	0.42396	0.15483	0.00165	0.03739	0.00171
	7	0.38046	0.42396	0.15483	0.00166	0.0374	0.00171
North America	1	0.39779	0.3982	0.20401	0	0	0
	2	0.33269	0.34065	0.23932	0.00224	0.08364	0.00146
	3	0.3299	0.33756	0.24475	0.00287	0.08312	0.00181
	4	0.32949	0.33714	0.24467	0.00287	0.08388	0.00195
	5	0.32941	0.33706	0.24463	0.00289	0.08404	0.00196
	6	0.3294	0.33706	0.24463	0.0029	0.08406	0.00196
	7	0.3294	0.33705	0.24463	0.0029	0.08406	0.00196
South America	1	0.53352	0.22895	0.00916	0.22837	0	0
	2	0.4756	0.21405	0.06142	0.21119	0.03624	0.0015
	3	0.47379	0.21337	0.06458	0.21043	0.03609	0.00174
	4	0.47345	0.21325	0.06468	0.21028	0.03652	0.00182
	5	0.47339	0.21323	0.06469	0.21027	0.03659	0.00182
	6	0.47338	0.21323	0.0647	0.21027	0.0366	0.00182
	7	0.47338	0.21323	0.0647	0.21027	0.03661	0.00182
Africa	1	0.38225	0.20909	0.00226	0.08507	0.32132	0
	2	0.33831	0.1956	0.09702	0.08532	0.28372	0.00003
	3	0.33417	0.19375	0.10174	0.08435	0.28502	0.00097
	4	0.33329	0.19339	0.10187	0.0843	0.28603	0.00111
	5	0.33315	0.19335	0.10191	0.08433	0.28613	0.00113
	6	0.33313	0.19335	0.10192	0.08434	0.28613	0.00113
	7	0.33313	0.19335	0.10193	0.08434	0.28613	0.00113
Middle East	1	0.07478	0.0365	0.05191	0.0008	0.00294	0.83308
	2	0.09808	0.03779	0.11491	0.04574	0.03782	0.66566
	3	0.09788	0.03876	0.11329	0.04843	0.04528	0.65636
	4	0.09776	0.03874	0.11325	0.04839	0.04637	0.65549
	5	0.09776	0.03873	0.11324	0.04841	0.04639	0.65546
	6	0.09776	0.03873	0.11324	0.04841	0.04639	0.65546
	7	0.09776	0.03873	0.11324	0.04841	0.04639	0.65546

*Notes: The decompositions are based on weighted-average price-earnings ratios in which the weights are based on market value in the representative countries for each continent.

※Source: Weekly stock market data from Bloomberg.

Middle East. Lastly, changes in price-earnings ratios in the Middle East explain the following proportions of price-earnings ratio changes: 33.3%-38.2% of Asia, 19.3%-20.9% of Europe, 0.23%-10.19% of North America, 8.43%-8.51% of South America, and 0.003%-0.11% of Africa.

6) Granger Causality

〈Table 5〉 shows the results of the Granger causality analyses performed based on weekly intercontinental price-earnings ratios during the 2007-2009 global financial crisis.²⁾

〈Figure 8〉 depicts the intercontinental Granger causality for each subperiod by use of arrows. In the figure, dotted lines indicate a lack of Granger causality and solid lines indicate statistically significant Granger causality.

〈Figure 8〉 shows no Granger causality of intercontinental price-earnings ratios during 1996, a stable period during which interconnectedness of stock prices among continents was relatively weak.

However, with the outbreak of the Asian foreign exchange crisis in 1997 and the LTCM crisis in 1998, global financial markets fell into chaos during 1997-1999. Sheng & Tu (2000) concluded that the U.S. stock market affected Asian stock markets during the Asian financial crisis, but the results of this study—based on analysis at the continental level rather than the national level—indicate that price-earnings ratios of North America had weak Granger causality with Asia but statistically significant Granger causality with Europe. Intercontinental Granger causality seems to have been weak at the time the crisis began.

When the World Trade Center in New York was attacked by terrorists on 9/11 in 2001, global financial markets fell into chaos again. Many continents exhibited Granger causality with one another at that time. The Middle East, with its many Islamic countries, had Granger causality with all other continents except Asia, and North America, which includes the United States, and Europe had mutual Granger causality. Such global circumstances greatly affected stock prices of other continents. In comparison to the stable period and the period of the Asian financial crisis, Granger causality among continents was demonstrated clearly during 2000-2001.

When the financial market contracted in 2002 as a result of the Enron scandal, the U.S. Federal Reserve Board initiated a quantitative easing monetary policy by increasing the key interest rate, the federal funds rate. 〈Figure 8(d)〉 shows Granger causality among continents during 2002-2004 under these market conditions. Despite the confusion and the intervention of the U.S. Federal Reserve, North America did not exhibit Granger causality with other continents. In comparison to 2000-2001, intercontinental Granger causality during 2002-2004 was relatively low.

〈Figure 8(e)〉 shows the results for the stable period of 2005-2006, after the financial crisis. Intercontinental Granger causality was remarkably low during that period compared to periods of financial crisis.

From 2007 to 2009, the world experienced a global financial crisis, with the bankruptcy of Lehman Brothers and the sudden drop in the Dow Jones index. As shown in 〈Figure 8(f)〉, many

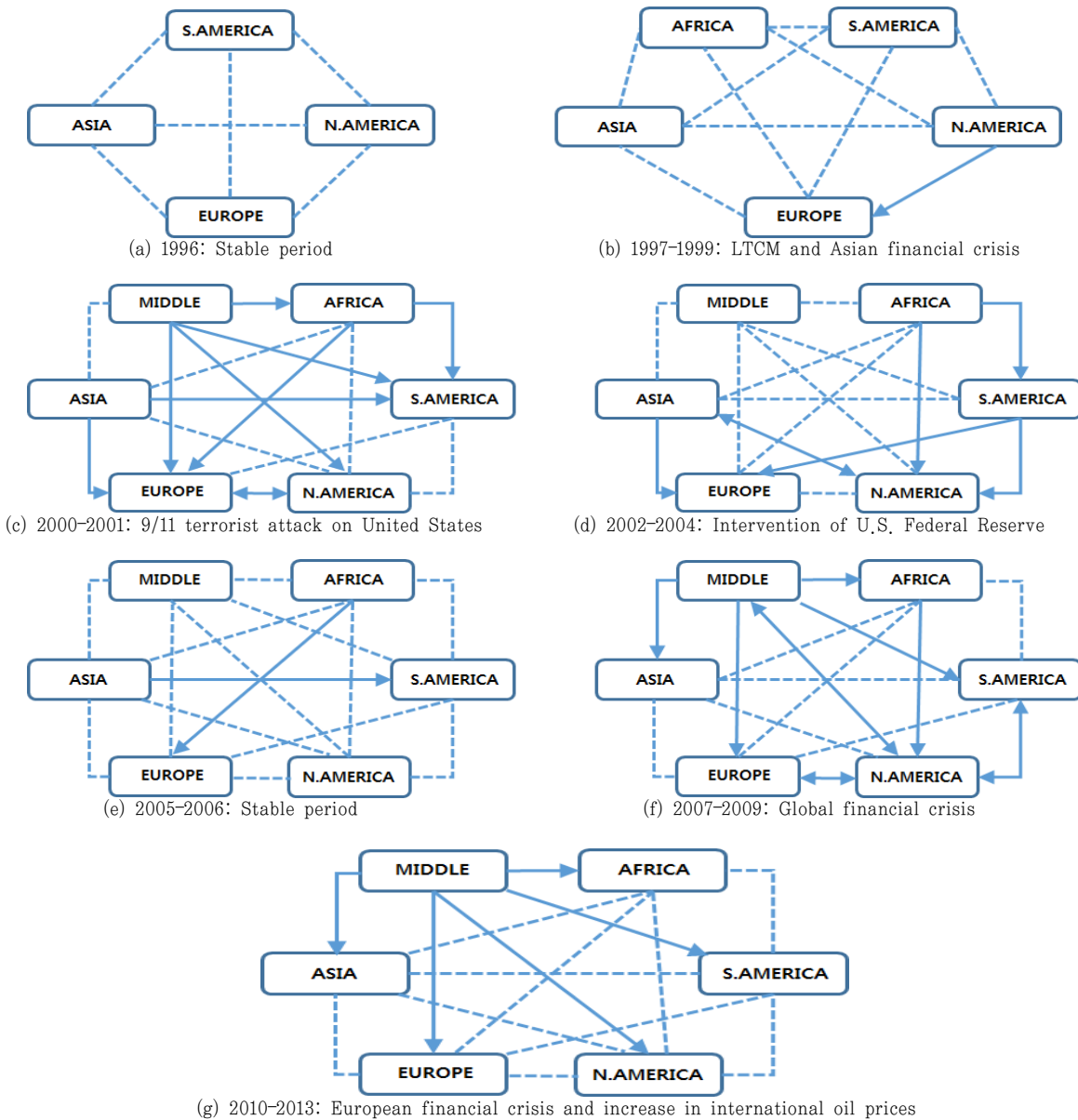
2) Causality results for other periods have not been provided in tabular form but are shown in 〈Figure 8〉.

Table 5. Granger causality Wald test results for intercontinental relationships in price-earnings ratios: Asia, 2007-2009

Test	DF	Chi-Square	Pr>Chi-Square
Asia does not Granger-cause Europe	1	2.75	0.0975
Asia does not Granger-cause North	1	10.20***	0.0014
Asia does not Granger-cause South	1	3.58	0.0585
Asia does not Granger-cause Africa	1	3.00	0.0834
Asia does not Granger-cause Middle East	1	1.04	0.3080
Europe, 2007-2009			
Test	DF	Chi-Square	Pr>Chi-Square
Europe does not Granger-cause Asia	1	0.22	0.6404
Europe does not Granger-cause North	1	29.22***	<0.0001
Europe does not Granger-cause South	1	1.13	0.2881
Europe does not Granger-cause Africa	1	1.67	0.1966
Europe does not Granger-cause Middle East	1	1.29	0.2566
North America, 2007-2009			
Test	DF	Chi-Square	Pr>Chi-Square
North does not Granger-cause Asia	1	2.02	0.1557
North does not Granger-cause Europe	1	17.91***	<.0001
North does not Granger-cause South	1	5.49**	0.0191
North does not Granger-cause Africa	1	0.07	0.7853
North does not Granger-cause Middle East	1	4.96**	0.0259
South America, 2007-2009			
Test	DF	Chi-Square	Pr>Chi-Square
South does not Granger-cause Asia	1	0.17	0.6839
South does not Granger-cause Europe	1	0.20	0.6533
South does not Granger-cause North	1	4.21**	0.0402
South does not Granger-cause Africa	1	1.94	0.1635
South does not Granger-cause Middle East	1	1.76	0.1842
Africa, 2007-2009			
Test	DF	Chi-Square	Pr>Chi-Square
Africa does not Granger-cause Asia	1	0.28	0.5982
Africa does not Granger-cause Europe	1	0.09	0.7617
Africa does not Granger-cause North	1	4.55**	0.0330
Africa does not Granger-cause South	1	0.01	0.9349
Africa does not Granger-cause Middle East	1	0.58	0.4449
The Middle East, 2007-2009			
Test	DF	Chi-Square	Pr>Chi-Square
Middle East does not Granger-cause Asia	1	6.68***	0.0098
Middle East does not Granger-cause Europe	1	8.21***	0.0042
Middle East does not Granger-cause North	1	18.15***	<.0001
Middle East does not Granger-cause South	1	20.78***	<.0001
Middle East does not Granger-cause Africa	1	17.89***	<.0001

*Notes: The regressions are based on weighted-average price-earnings ratios in which the weights are based on market value in the representative countries for each continent. ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

※Source: Weekly stock market data from Bloomberg.



*Note: Dotted lines indicate a lack of causality; solid lines indicate statistically significant causality.

※Source: Weekly stock market data from Bloomberg.

Figure 8. Granger causality Wald test results for intercontinental relationships in price-earnings ratios by subperiod, 1996-2013

continents exhibited Granger causality during 2007-2009. Intercontinental Granger causality was extremely high during that period compared to other periods of financial crisis. Didier, *et al.* (2011) argued, based on analysis of stock price movement during times of international financial crisis, that comovement of stock prices is affected more by financial interconnectedness than by trade and that stock prices in countries that have

vulnerable banking and corporate sectors exhibit greater comovement with U.S. stock prices. During the global financial crisis, such strong financial interconnectedness was demonstrated that many continents exhibited Granger causality of stock prices.

The global financial market once again fell into chaos during 2010-2013, due to the European financial crisis, and international oil prices

increased sharply. Financial markets throughout Europe contracted as a result of Greece's high default risk and Europe's financial instability, but the European crisis had no significant effect on stock prices of other continents. However, (Figure 8(g)) indicates that the Middle East's price-earnings ratios exhibited Granger causality with all continents, as a result of the increased oil prices. This finding is consistent with Gogineni(2010)'s argument that price-earnings ratios are heavily dependent on oil prices and that even industries that seldom use petroleum are greatly affected by oil prices because their primary customers are affected by oil prices.

IV. CONCLUSIONS

In this study, analysis of the comovement of stock prices within continents has verified that the correlation of stock prices among countries in the same continent is greatly increased during large-scale financial crises that affect all continents. Granger causality testing has shown that the stock prices of each continent did not mutually affect the stock prices of other continents when financial markets were relatively stable. However, greater Granger causality among continents was exhibited during 2000-2001, which included the 9/11 terrorist attack on the United States, and the global financial crisis of 2007-2009. Between 2010 and 2013, the Middle East affected the stock prices of other continents via increased international oil prices.

This study has examined the comovement of stock prices within continents during specific periods, based on the hypothesis that intercontinental Granger causality exists. However, since testing of

a hypothesis provides merely a statistical determination of true or false, the analysis does not provide estimates of crisis transition time, rate, or direction. More systematic analysis can be performed in the future by studying the time, path, and direction of the dispersion of financial crises across continents. Such analysis could help in controlling the risk of international crises and enable countries and individual investors to devise effective investment strategies.

Acknowledgement

This research was supported by a grant from the Asian Institute of Corporate Governance (AICG) at Korea University.

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Received: Dec. 20, 2017 / Revised: Jan. 5, 2018 / Accepted: Jan. 12, 2018

금융 위기 시 글로벌 주식시장의 연결성

국문초록 본 연구는 금융 위기 발생 시 대륙간의 금융시장이 어떻게 연결되어 반응하는지를 보이고자 한다. 이를 위해 주식 가격의 움직임과 인과 관계를 분석한다. 각 대륙 주식의 price-earnings 비율의 움직임 분석을 통해 금융 위기 기간 동안의 증대된 동일 방향으로의 움직임이 존재한다는 것을 검증한다. 또한, 시계열 데이터를 단위근 시계열, 공적분, 벡터 자기회귀 (VAR) 모델, 임펄스 응답, 예측 오차 분산 분해 및 Granger 인과 관계의 방법을 사용하여 분석한다. 그 결과 금융 위기가 발생했을 때 대륙간 주식의 price-earnings비율에 대한 Granger 인과성이 증가하는 것을 관찰할 수 있다. 또한 마지막으로 금융 위기 동안 충격의 대륙간 이동 경로를 확인할 수 있다. 이러한 분석들이 국제 위기의 위험을 통제하고 국가 및 개인 투자자가 효과적인 투자 전략을 고안하는 데 도움이 될 것으로 기대한다.

주제어 : 금융위기, 글로벌 주식시장, Granger 인과성, 벡터자기회귀(VAR)모형, 임펄스 응답

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