Price and Volatility Spillover Effects between Japanese and Korean Stock Markets

Sang Hoon, Kang, Su-Do, Kim, Hwan-Gue, Cho, and Seong-Min Yoon

Abstract**—**This study investigates the intraday price and volatility spillover effect between the Japanese market and the Korean market, using a VAR-asymmetric BEKK GARCH model. The empirical results indicate a uni-directional price spillover from the TOPIX market to KOSPI 200 market. Regarding the volatility spillover effect, the estimation of the asymmetric BEKK GARCH model indicates weak evidence of bi-directional volatility spillover. In addition, the cross-market asymmetric response is evident from the TOPIX market to the KOSPI 200 market. These findings provide an important guideline on arbitrage strategies and risk management.

Keywords**—**VAR-Asymmetric BEKK GARCH model, Intraday data, spillover effect, KOSPI 200, TOPIX

I. Introduction

THE issue of financial market integration is of interest in understanding market price spillover and volatility spillover effects from one market to another. Such a spillover effect in finance is the most important concept in building the optimal risk portfolios for international portfolio managers and risk managers [1-3]. In short, the dynamics of price spillover effects provide price predictions and an opportunity for an exploitable trading strategy, which constitutes evidence against market efficiency [4]. In addition, information about volatility spillover effects may be useful for applications that rely on estimates of conditional volatility, such as option pricing, portfolio optimization, management of value-at-risk, and risk hedging [5-6].

Recent econometric studies have developed advanced techniques in capturing the spillover effects, i.e., multivariate generalized autoregressive conditional heteroskedasticity (GARCH)-type models [7]. In spite of these effects, prior studies are limited to detecting spillover effects as they utilize low frequency data that do not capture uncovered intraday information transmission among financial markets. With the development of information technology (IT), researchers easily access the high frequency data that provide more reliable information for examining the spillover effect within a very short time.

In this paper, we focus on the issue of price and volatility spillovers between the Tokyo Stock Price Index (TOPIX) and the Korea Composite Stock Price Index 200 (KOSPI 200), in order to provide an important insight into the mechanism of information transmission between the two equity markets. In so doing, this paper utilizes the VAR-asymmetric BEEK GARCH model in 30-min intraday data.

Our empirical results support strong linkages between Japanese and Korean stock markets. This information provides important implications for intraday traders in implementing arbitrage trading strategies, and also for portfolio managers in risk management. Intraday traders must take into account uni-directional asymmetric spillover effects in order to optimize arbitrage trading strategies in very short time intervals. In addition, risk-averse investors assess market portfolio risk by measuring the volatility spillover effects between two stock markets.

The rest of this paper is organized as follows. Section 2 provides the descriptive statistics of 30-min intraday data. Section 3 discusses the econometric methodology used in this study. Section 4 provides the results, and several conclusions are discussed in Section 5.

II. Data

We considered 30-min time interval data of the TOPIX and KOSPI 200 markets. Intraday datasets cover the period from January 4, 2011 to December 28, 2012, obtained from the database of SIRCA.[1] The sample series were then converted into logarithmic return series for all sample indices, that is, $R_{i,t} = \ln\left(P_{i,t}/P_{i,t-1}\right)\times 100$, where $R_{i,t}$ denotes the continuously compounded percentage returns for index i at time t and $P_{i,t}$ denotes the price level of index i at time t.

Table 1 shows the descriptive statistics and the results of the unit root tests for 30-min intraday return series. As shown in Panel A of Table 1, the return series show very similar descriptive statistics. According to skewness (Skew.) measured at the third standardized moment, excess kurtosis (Kurt.) measured at the deviation of the fourth moment from three of the normal distribution, and the Jarque-Bera (J-B) test results for Gaussian distribution of the observed probability distribution, the return series tend to follow a leptokurtic distribution with a

Sang Hoon, Kang is with the Department of Business Administration, Pusan National University, Busan, 609-735, South Korea(corresponding author's phone: +82-51-510-2558 ; e-mail: sanghoonkang@pusan.ac.kr).

Su-Do, Kim is with the Research Institute for Social Criticality, Pusan National University, Busan, 609-735, South Korea (e-mail: kimsd@pusan.ac.kr).

Hwan-Gue, Cho is with the Department of Computer Science and Engineering, Pusan National University, Busan, 609-735, South Korea (e-mail: hgcho@pusan.ac.kr).

Seong-Min, Yoon is with the Department of Economics, Pusan National Univeristy, Busan, 609-735, South Korea (e-mail: smyoon@pusan.ac.kr).

[1] We remove the observations of lunch break (11:30 a.m. to 12:30 p.m.) to couple trading time intervals between the TOPIX market and the KOSPI 200 market.

higher peak and a fatter tail than the case of a normal distribution.

TABLE I
DESCRIPTIVE STATISTICS AND UNIT ROOT TESTS

	TOPIX	KOSPI 200
Panel A: Descriptive statistics		
Mean	-0.0010	-0.0006
Std. Dev.	0.3531	0.4005
Maximum	3.7668	3.6324
Minimum	-6.1185	-5.5663
Skewness	-1.7602	-1.6815
Kurtosis	56.271	42.815***
Jarque-Bera	616111***	345123***
Panel B: Unit root tests		
ADF	-65.906***	-64.640***
PP	-65.784***	-68.674***

Notes: *** indicates the rejection of the null hypothesis at the 1% level of significance.

Panel B of Table 1 provides the results of two types of unit root tests for the stationarity of individual series: standard parametric augmented Dickey-Fuller (ADF) tests and non-parametric Phillips-Peron (PP) tests. These two ADF and PP test results with large negative values reject the null hypothesis of a unit root at the 1% levels of significance, respectively. Thus, all return series used in this study could be regarded as stationary ones.

III. METHODOLOGY

This section introduces the VAR-asymmetric BEKK GARCH model that incorporates the price spillover and asymmetric volatility spillover between two market intraday variables [8]. Consider the following bivariate VAR(1) models to examine the Granger-causal relationship between two stock markets:[2]

$$\begin{bmatrix} R_{i,t} \\ R_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} R_{1,t-1} \\ R_{2,t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}, \quad (1)$$

where $R_{1,t}$ and $R_{2,t}$ are TOPIX and KOSPI 200 intraday returns, respectively. μ_1 and μ_2 are constants and ε_1 and ε_2 are error terms. The coefficients, γ_{12} and γ_{21} capture the effect of the Grange-causal relationship between two markets. For example, the significance of γ_{21} means that TOPIX intraday returns Granger-cause the KOSPI 200 intraday returns. The diagonal terms γ_{11} and γ_{22} measure their own lagged effects.

We further analyze the asymmetric volatility spillover between two markets, using the asymmetric BEEK GARCH model. By allowing the time-varying conditional variance of $\varepsilon_{i,t}$, H_t is a 2×2 matrix of conditional variance-covariance at time t. The market information available at time $t-1$ is represented by the information Ω_{t-1} in Equation (2):

$$\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} | \Omega_{t-1} \sim N(0, H_t) \cdot \quad (2)$$

An asymmetric BEKK GARCH model of Kroner and Ng [9], which extended the GJR-GARCH approach of Glosten, Jagannathan and Runkle [10] to a multivariate setting to capture the asymmetric response to news on volatility can be represented as follows:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + D'\eta_{t-1}\eta'_{t-1}D\,, \quad (3)$$

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & \\ c_{21} & c_{22} \end{bmatrix}' \begin{bmatrix} c_{11} & \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$
$$+ \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$
$$+ \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}' \begin{bmatrix} \eta_{1,t-1}^2 & \eta_{1,t-1}\eta_{2,t-1} \\ \eta_{2,t-1}\eta_{1,t-1} & \eta_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}, \quad (4)$$

where H_t is a 2×2 matrix of conditional variance-covariance at time t; C is a 2×2 lower triangular matrix with three parameters; A is a 2×2 square matrix of parameters and indicates the extent to which conditional variances are correlated to past squared errors; and B is a 2×2 squared matrix of parameters and indicates the extent to which current levels of conditional variances are related to those of past conditional variances. The off-diagonal elements of the matrices A and B capture cross-market effects, including shock spillovers (a_{12} and a_{21}) and volatility spillovers (b_{12} and b_{21}) between TOPIX and KOSPI 200 markets.

In Equation (4), $\eta_{t-1} = \begin{bmatrix} \max(0, -\varepsilon_{1,t-1}) \\ \max(0, -\varepsilon_{2,t-1}) \end{bmatrix}$, D is a 2×2 squared matrix of parameters and captures any asymmetry in variances and covariance through the definition of η_{t-1}. The significances of diagonal coefficients d_{11} and d_{22} capture evidence of an asymmetric response to negative shocks (bad news) to itself for both markets. Likewise, the significances of off-diagonal coefficients d_{21} and d_{12} examine the cross-market effect of volatility asymmetric response.

The parameters of the bivariate GARCH model can be estimated by the maximum likelihood estimation method optimized with the Berndt, Hall, Hall and Hausman (BHHH) algorithm. The conditional log likelihood function $L(\theta)$ is expressed as:

$$L(\theta) = -T\log 2\pi - 0.5\sum_{t=1}^{T}\log\left|H_t(\theta)\right| - 0.5\sum_{t=1}^{T}\varepsilon_t(\theta)' H_t^{-1}\varepsilon_t(\theta)\,, \quad (5)$$

where T is number of observations and θ denotes the vector of all the unknown parameters.

IV. EMPIRICAL RESULTS

This section considers price spillover and volatility spillover effects between two markets, using the VAR-asymmetric BEEK GARCH model. Table 2 shows the estimation results of the

[2] The optimal lag order of VAR model was determined by the Akaike information criterion (AIC).

VAR(1)-asymmetric BEKK GARCH model using intraday returns of three time intervals. The estimation results provide several interesting findings.

TABLE II
ESTIMATION OF PRICE AND VOLATILITY SPILLOVER EFFECTS

	Coefficient(s)	Standard error
Mean equation: VAR estimation		
μ_1	0.0190	(0.0384)
μ_2	0.0212	(0.0404)
γ_{11}	0.0408***	(0.0148)
γ_{12}	0.0023	(0.0127)
γ_{21}	-0.0549***	(0.0170)
γ_{22}	0.0867***	(0.0170)
Variance equation:		
c_{11}	0.5163***	(0.0272)
c_{21}	0.1247***	(0.0198)
c_{22}	0.2223***	(0.0152)
a_{11}	0.0001	(0.0264)
a_{12}	-0.0000	(0.0077)
a_{21}	-0.0000	(0.0184)
a_{22}	0.0000	(0.0173)
b_{11}	0.9713***	(0.0027)
b_{12}	-0.0009	(0.0017)
b_{21}	0.0144***	(0.0017)
b_{22}	0.9928***	(0.0011)
d_{11}	0.1800***	(0.0121)
d_{12}	0.0044	(0.0075)
d_{21}	-0.0768***	(0.0118)
d_{22}	0.1390***	(0.0090)

Notes: Standard errors are in parentheses. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively.

First, we consider the mean spillover effects between two markets in VAR(1) estimation results. The significance of coefficient, γ_{21}, indicates an uni-directional relationship from the TOPIX market to the KOSPI market. In addition, we find that only the coefficient γ_{21} is negatively significant, indicating that the TOPIX intraday returns have a negative impact on the KOSPI 200 intraday returns.

Second, we now turn to volatility spillover effect between the two markets. The off-diagonal elements in B (i.e., b_{12} and b_{21}) depict the extent to which the conditional variance of one variable is correlated with the lagged conditional variance of another variable. The estimation results of the 30-min interval suggest a uni-directional volatility spillover from the TOPIX market to the KOSPI 200 market.

Third, as far as matrix D is concerned, we find evidence of an asymmetric response to negative shocks (bad news) to itself for both markets due to the significance of coefficients d_{11} and d_{22}. In addition, the cross-market asymmetric response is evident from the TOPIX market to the KOSPI 200 market, as the coefficient d_{21} is negatively significant in all time intervals. This means that bad news in the TOPIX market leads to a smaller volatility in the KOSPI 200 market than does good news in the TOPIX market.

Overall, the evidence shows uni-directional spillover effects from the TOPIX market to the KOSPI 200 market. In addition, this study finds asymmetric volatility response effects from the TOPIX market to the KOSPI 200 market. Thus, we conclude that the TOPIX market leads the KOSPI 200 market in price and asymmetric volatility.

V. CONCLUSION

This study has investigated the intraday price and volatility spillovers between the TOPIX and KOSPI 200 using a VAR-asymmetric BEEK GARCH model. In this study, we considered 30-min returns in order to investigate the intraday spillover effects between the Japanese and Korean stock markets. This investigation of intraday spillover effects will provide intraday traders with a deeper understanding of short-time price and volatility transmission in both markets.

Our empirical results are summarized as follows. First, we found an uni-directional price spillover from the TOPIX market to KOSPI 200 market. Second, the estimation of the asymmetric BEKK GARCH model indicates evidence of uni-directional volatility spillovers from the TOPIX market to the KOSPI 200 market. Third, the cross-market asymmetric response is evident from the TOPIX market to the KOSPI 200 market.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation granted by the Korean Government (NRF-2013S1A5B6053791). This work was supported by the National Research Foundation granted by the Korean Government (NRF-2011-330-B00044).

REFERENCES

[1] D. Kenourgios, A. Samitas, and N. Paltalidis, "Financial crises and stock market contagion in a multivariate time-varying asymmetric framework," *Journal of International Financial Markets, Institutions and Money*, vol. 21, no. 1, pp. 92-106, 2011. http://dx.doi.org/10.1016/j.intfin.2010.08.005

[2] M. N. Syllignakis, and G. P. Kouretas, "Dynamic correlation analysis of financial contagion: evidence from the Central and Eastern European markets," *International Review of Economics & Finance*, vol. 20, no. 4, pp. 717-732, 2011. http://dx.doi.org/10.1016/j.iref.2011.01.006

[3] J. C. Reboredo, "Volatility spillovers between the oil market and the European Union carbon emission market", *Economic Modelling*, vol. 36, pp. 229-234, 2014. http://dx.doi.org/10.1016/j.econmod.2013.09.039

[4] P. C. Pati, and P. Rajib, "Intraday return dynamics and volatility spillovers between NSE S&P CNX Nifty stock index and stock index futures," *Applied Economics Letters*, vol. 18, no. 6, pp. 567-574, 2011. http://dx.doi.org/10.1080/13504851003742442

[5] M. E. H. Arouri, J. Jouini, and D. K. Nguyen, "Volatility spillovers between oil prices and stock sector returns: implications for portfolio management", *Journal of International Money and Finance*, vol. 30, no. 7, pp. 1387-1405, 2011. http://dx.doi.org/10.1016/j.jimonfin.2011.07.008

[6] M. E. H. Arouri, J. Jouini, and D. K. Nguyen, "On the impacts of oil price fluctuations on European equity markets: volatility spillover and hedging effectiveness", *Energy Economics*, vol. 34, no. 2, pp. 611-617, 2012. http://dx.doi.org/10.1016/j.eneco.2011.08.009

[7] L. Bauwens, S. Laurent, and J. V. K. Rombouts, "Multivariate GARCH models: a survey", *Journal of Applied Econometrics*, vol. 21, no. 1, pp. 79-109, 2006.
http://dx.doi.org/10.1002/jae.842

[8] R. Engle, "Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models", *Journal of Business & Economic Statistics*, vol. 20, no. 3, pp. 339-350. 2002.
http://dx.doi.org/10.1198/073500102288618487

[9] K. F. Kroner, and V. K. Ng, "Modeling asymmetric comovements of asset returns", *Review of Financial Studies*, vol. 11, no. 4, pp. 817-844, 1998.
http://dx.doi.org/10.1093/rfs/11.4.817

[10] L. R. Glosten, R. Jagannathan, and D. E. Runkle, "On the relation between the expected value and the volatility of the nominal excess return on stocks", Journal *of Finance*, vol. 48, no. 5, pp. 1779-1801, 1993.
http://dx.doi.org/10.1111/j.1540-6261.1993.tb05128.x