Macrothink Institute™

Business and Economic Research
ISSN 2162-4860
2025, Vol. 15, No. 2

# The Time Decaying Synchronization between the Volatility Index and KOSPI Return

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Received: January 22, 2025 Accepted: February 21, 2025 Published: February 22, 2025

doi:10.5296/ber.v15i2.22559 URL: https://doi.org/10.5296/ber.v15i2.22559

**Abstract**

This study examines the spillover effect of the volatility index on the stock return of the Korean stock market. Empirical analysis utilizes the US volatility index (VIX) in the return format and the KOSPI daily return data for the twenty years from January 2002 to December 2021. Using the time-series models, I find that the VIX is negatively associated with the KOSPI stock return. Further, the result shows that the influence of the VIX becomes weakened in the later period after the financial crisis. Nevertheless, the negative relation between the VIX return and the KOSPI return remains persistent, suggesting that the VIX serves as a preceding indicator for the Korean stock market.

**Keywords:** Synchronization, Volatility index, Spillover, Stock return

## 1. Introduction

The integration of the international capital markets have been rapidly evolved during 2000's. As a consequence, the social and economic shock occurred in one country spills over to other countries and increases uncertainty in the global economy. Recently, the financial crisis in year 2008 and the pandemic crisis in year 2020 lead to the global oversupply of liquidity through quantitative easing in the government effort to overcome the crisis. In the process, the global stock markets have experienced extreme volatility.

The synchronization of international stock markets has accelerated as the financial markets are integrated due to the liberalization of financial markets and the development of the speed of information transmission. As a result, the issues in the US stock market have a major impact on financial markets in other countries, and furthermore, there is a phenomenon of synchronization where the domestic stock market follows the movement of the US market. Academic research provides the evidence of the synchronization between the US and Korean

stock markets. Khil (2003) argues that the shock in the US stock market immediately transferred to the Korean and Japanese markets. Choi and Cho (2017), although the degree of synchronization among the Korean, US, and Chinese stock markets appears different due to the differences in the financial market environment, the Korean stock market generally shows a strong degree of synchronization with the US and Chinese stock markets.

More recently, academic research examines the cross-county impact of various indicators that are related to the stock market. One of them is the volatility Index. Volatility index VIX) is a key indicator that shows the possibility of the stock market fluctuation due to uncertainty. An increase in the volatility index can be interpreted as the uncertainty of the stock market will increase in the future. The volatility index is an index representing investors' expectation for the next 30 days of the S&P 500 index option listed on the Chicago Board Options Exchange (CBOE). The volatility Index (VIX) quantifies investors' investment sentiment about market conditions and thus the volatility of the US stock market. For example, VIX of 20 suggests that investors expect the stock index to rise and fall by 20% over the next month. As VIX increases, it means that there are many investors who want to sell stocks and exit by predicting higher volatility of the stock market, and the stock price is trending down in the future.

In this paper, I study whether investors in the Korean stock market can refer to the VIX index as a leading indicator to reduce investment risk. Specifically, I examine the impact of the VIX return on the return of the Korean stock market using the daily return data from January 2002 to December 2021. For comparative analysis, the VIX return on t-1 is matched to the Korean stock market return on t-day. The stock return for the Korean stock market is the daily return on the KOSPI index. The empirical analysis utilizes time-series analysis including the GARCH-M (Generalized Autoregressive Conditional Heteroskedasticity in Mean) model, which provides a robust estimate adjusted for the time-series autocorrelation and heteroskedasticity in the stock return data.

The results show that the VIX return is negatively associated with the KOSPI index return. Thus, the volatility of the US market spills over to the Korean stock market. This suggests that it is possible to predict the movement of the Korean stock market in the next day by referring to the movement of the VIX in the previous day. Further analysis shows that the volatility spillover effect is reduced by more than half in recent years since the financial crisis. The result suggests that the influence of the US stock market has been reduced over time.

The remainder of the paper is organized as follows. In Section 2, I discuss the related literature. Section 3 describes the sample selection procedure and provides descriptive statistics. Section 4 presents the results of the time-series analysis and conducts additional tests on the time-decaying effect of the volatility spillover. Section 5 concludes the paper.

## 2. Related Literature and Hypotheses

Previous literature examines the synchronization of the global financial markets where the issues in one stock market transfer to the stock markets in other countries. Most of these studies analyze the co-movement of stock returns and/or volatility across the global stock

markets and the direction of the spillover effect. Eun and Shim (1989) examine the synchronization of the daily stock returns among the stock markets of nine major developed countries (the United States, Canada, Germany, France, Switzerland, the United Kingdom, Hong Kong, Japan, and Australia) and found that the direction of synchronization is from the US market to other countries, and not vice versa. Hamao et al. (1990) tests the cross-country spillover effects in the stock return and volatility for the UK, the US, and Japanese stock markets. The results shows that the UK and the US stock markets influence the Japanese market, and not in the other way. Frank and Hesse (2009), Yiu et al. (2010), and Bekiros (2014) argue that the synchronization among developed and emerging stock markets has increased further after the financial crisis.

For the Korean stock market, several studies examine the synchronization and spillover effect between the US market and the Korean market. Koh (2007) argue that the stock return of Korean stock market is affected by the movement of the S&P 500 index return in the previous day. Furthermore, Kim and Moon (2010) and Park et al. (2022) find that the influence of the US stock market on the Korean stock market has declined after the financial crisis. Choi and Kang (2014) add that while the influence of the US market declined after the financial crisis, the influence of the Chinese market has increased. On the other hand, Choi and Cho (2017) find that the synchronization of the stock return among the Korean, US, and Chinese stock markets are persistent even after the financial crisis, although less so for the volatility transfer effect.

In sum, previous literature suggests that the synchronization of the US stock market and the Korean stock market. However, these studies examine the synchronization of the stock return and volatility separately. Contrary, I examine the effect of the volatility transfer to the stock return, i.e. the impact of the movement of VIX, which is an indicator of volatility, on the stock return of the Korean stock market. I also test whether the spillover effect of volatility between VIX and the stock return of the Korean stock market has altered over time during the 2001 to 2021 period.

## 3. Sample Selection

I utilize the daily return data on the CBOE volatility index (VIX) and the KOSPI index from January 3, 2002 to December 31, 2021. The data begins in year 2002 when Korea joined the WTO (World Trade Organization) and thus the Korean capital market began to be closely linked to the international capital market. The test period includes the global financial crisis in year 2008 and the pandemic period of year 2020 to 2021. During these crisis periods, the volatility index spiked to over 80. I also examine the time-varying impact of the VIX on the KOSPI index by dividing the sample period into the four sub-periods in five-year intervals.

In the empirical tests, I use the daily volatility index return and examine the co-movement with the daily stock return of the KOSPI Index. Because the daily VIX return and the stock return are both highly skewed and their time-series data shows high kurtosis, the return is measured with the log value. Specifically, the VIX return is calculated using the log value of daily data. Similarly, the daily return of the KOSPI index is the log value of daily return data. There are 4,796 daily return data available during the sample period.

Table 1 provides the definitions and formulas of the variables used in empirical analysis. The trading hours of the US stock market are from 10:30 p.m. on the day t-1 to 5:00 a.m. on the day t (11:30 p.m. to 6:00 a.m. when summer time is off) based on the calendar date, and the Korean stock market is from 9:00 a.m. on the day t to 3:30 a.m. on the same day T. For comparative analysis, the VIX return is measured at t-1 and analyzed whether this had an impact on the Korean stock market at t, the next day. When the Korean and the US stock markets are closed, the VIX return on the day just before the holiday is linked to the opening date of the Korean stock market. As a result, there is an interval of the maximum 4 days.

Table 1. Definition of variables

| Variables | Return Equation | Definition |
|---|---|---|
| Volatility Index Return | $Ln(VIX_{t-1}/VIX_{t-2})$ | Daily return on VIX index at time t-1 |
| KOSPI Index Return | $Ln(KOSPI_t/KOSPI_{t-1})$ | Daily return on KOSPI index at time t |

## 4. Empirical Results

In this section, I examine the impact of the VIX return on the KOSPI return for the extended time period. As the increase in the CBOE volatility index implies higher uncertainty in the US stock market, the adverse market sentiment spills over to the Korean stock market in the next day and causes a negative pressure on the stock return. Thus, it is expected that the VIX return and the KOSPI return is negatively correlated.

I utilize the time-series modeling to control for the time-series autocorrelation in the VIX returns and the KOSPI returns.

### *4.1 Descriptive Statistics and the Correlation Analysis*

Table 2 is the descriptive statistics of the variables for the entire sample period. VIX value itself surges to its historical maximum of 82.69 during the financial crisis in year 2008 and the COVID-19 pandemic in year 2020. It is known that VIX value greater than 20 indicates heightened uncertainty in the financial market. When there is a rapid surge in VIX value or thus the sharp increase in the VIX return, the domestic market stock index is expected to plummet.

Table 2 shows the daily returns for the VIX index and the KOSPI index. VIX index return is the daily return of the VIX index measured at the time t-1 based on the Korean calendar date. KOSPI index return is the daily return for KOSPI Index at the time t on the Korean calendar date. VIX return has an average of -0.006% and a median of 0.564%, while the corresponding numbers for the KOSPI index return are 0.029% and 0.078%, respectively.

Next, Table 2 shows the correlation analysis between the VIX return and the KOSPI return. The volatility index itself does not show a correlation with the KOSPI return. Therefore, the volatility index is converted into a return format, the VIX return.

Table 2. Descriptive statistics and correlation

| | *Volatility Index Return* | *KOSPI Index Return* |
|---|---|---|
| Mean | -0.006% | 0.029% |
| Median | 0.564% | 0.078% |
| Standard Deviation | 7.397% | 1.337% |
| Minimum | -35.059% | -11.172% |
| Maximum | 76.825% | 11.284% |
| Pearson Correlation | -0.307*** | |
| Number of Observations | 4,796 | |

*Note.* *** indicates statistically significant at 1% significance level.

The VIX return has a negative correlation with the KOSPI return. The correlation coefficient is -0.307 and it is statistically significant at the 1% significance level. In other words, when the volatility index increases, the market participants expect that the volatility in the US stock market will expand in the future and thus the expected uncertainty is transferred to the Korean stock market and leads to a decline in the Korean stock index. Therefore, the result is consistent with the view that the increase in the VIX return causes the decrease in the KOSPI index return. Because there is the time-series autocorrelation and heteroskedasticity in the return data, the next chapter considers the influence of these statistical issues and more closely analyzes the impact of the VIX return on the KOSPI index return using the time-series models.

### *4.2 The Analysis of the Relation between the VIX Return and the KOSPI Return*

In this study, the impact of VIX return on the KOSPI index return is analyzed with the time-series models. The return data is affected by the time-series autocorrelation and shows heteroskedasticity (Engle et al., 1987; Berndt, 1991; Elyasiani and Mansur, 2004; Mills, 2008).

The time-series models used in this study consist of a model where conditional variance, which indicates the estimated volatility based on information from the variance equation up to the t-1 point in time, is used as a proxy variable for the volatility to influence the stock return. The time-series models used in the paper include ARCH, ARCH-GARCH, and GARCH-M models. The GARCH-M (Generalized Autoregressive Conditional Heteroskedasticity in Mean) model is introduced by Engle et al. (1987). The GARCH-M model is useful in the financial field to analyze the time-series stock return data and considers the time-series autocorrelation and heteroskedasticity.

Table 3 shows the results using the time-series models to test the impact of the VIX return on the KOSPI return. In model (1), ARCH model is used with the time lag 1. The effect of the previous day's VIX return on the next day's KOSPI return (KOSPIR) is -0.05535 and it is significant at the 1% significance level. In terms of economic importance, the increase in the VIX return by one standard deviation is associated with the drop of the KOSPI return by

-0.4094% (=-0.05535*0.07397). Considering that the average KOSPI return is 0.029%, this means that the KOSPI index responds 14 times more sensitively than the daily return movement of the KOSPI index. Thus, it has an important economic impact. Next, a time-invariant element in the variance equation is generally insignificant with the KOSPI index return. ARCH parameter values that are time-dependent are all larger than 0 and significant at the 1% significance levels. Thus, ARCH model, that takes into account the time-series autocorrelation used in the analysis, is suitable for the analysis.

Table 3. The impact of the VIX return on the KOSPI index return

| | (1)<br>ARCH | (2)<br>ARCH-GARCH | (3)<br>GARCH-M |
|---|---|---|---|
| Constant | 0.00035**<br>(2.24) | 0.00040***<br>(2.60) | -0.00022<br>(-0.70) |
| Volatility Index Return | -0.05535***<br>(-33.15) | -0.05166***<br>(-28.89) | -0.05181***<br>(-28.90) |
| ARCH Lag(1) | 0.35838***<br>(20.89) | 0.27005***<br>(15.30) | 0.27270***<br>(15.22) |
| GARCH Lag(1) | | 0.82317***<br>(19.48) | 0.80714***<br>(19.10) |
| ARCHM Sigma2 | | | 4.97821**<br>(2.24) |
| $Chi^2$ Test | 1,098.82*** | 834.43*** | 835.55*** |
| N | 4,796 | 4,796 | 4,796 |

*Note.* The numbers in parentheses are heteroscedasticity-robust z-statistics. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

In model (2), the ARCH-GARCH model is used with parameters of (1,1). The result is similar to that of the ARCH model (1). The coefficient on the VIX return is -0.05166 and it is significant at the 1% significance level. ARCH and GARCH parameter values that are time-dependent are all larger than 0 and significant at the 1% significance levels.

In model (3), the GARCH-M model is used with parameters of (1,1) and the mean value of ARCH. Similar to the previous models, the coefficient on the VIX return is -0.05181 and it is significant at the 1% significance level. ARCH and GARCH parameter values that are time-dependent are all larger than 0 and significant at the 1% significance levels. ARCHM Sigma 2, which shows the effect of volatility or conditional variance, appears to be significant at the 5% significance level. This suggests that the impact of the return volatility on the stock index return is limited. The result indicates that the GARCH-M model, which takes into account the time-series autocorrelation and heteroskedasticity. In the following analysis in the next section, I use the GARCH-M model.

*4.3 The Time-decaying Influence of the VIX Return on the KOSPI Index Return*

It is argued that the spillover effect of the volatility from the US stock market to the Korean stock market is reduced after the financial crisis in year 2008. Some argues that the synchronization among the international capital markets has been gradually reduced in the recent years. Kim and Moon (2010) show that after the financial crisis, the influence of the stock return and volatility from the US market to the Korean stock market is decreased compared to the previous periods. Contrary, Choi and Cho (2017) suggest that even after the financial crisis, the synchronization between the Korean, US, and Chinese stock markets remains strong, while the volatility spillover varied from time to time. Choi and Kang (2014) and Bae and Ryu (2021) argue that the influence of the US stock market on the Korean stock market has declined after the financial crisis, while the influence of the Chinese market has increased. Because the MSCI Emerging Markets Index includes both the Korean and Chinese stock markets, the expanded influence of passive funds results in higher synchronization between the two stock markets. Conversely, the decoupling with the US stock market, which is a developed market, intensified. In sum, it is arguable that the influence of the VIX return could be altered over time. In the following analysis, I examine the changes in the influence of the VIX return on the KOSPI index return over time.

In Table 4, the impact of the VIX return on the KOSPI return is examined over the four sub-periods: year 2002 to 2006, year 2007 to 2011, year 2012 to 2016, and year 2017 to 2021. The sub-period tests show the time-decaying change in the influence of the VIX return on the KOSPI return.

From Table 4 model (1), the impact of the VIX return on the KOSPI index return is significantly negative, -0.07989, in the period of year 2002 to 2006. In model (2) where the test period is from year 2007 to 2011, the negative impact of the VIX return on the KOSPI index return is increased to -0.08316. This suggests that the high volatility in the second sub-period causes higher synchronization in the Korean stock market. However, the influence of the VIX return decreases to -0.03728 in the sub-period of year 2012 to 2016 of model (3) and then -0.02663 in the sub-period of year 2017 to 2021 of model (4). These findings confirm that the negative effect of the VIX return on the KOSPI index return is significantly weakened over time, especially after the financial crisis. Looking at the magnitude of the decline in the coefficients, the spillover effect of the volatility from the US stock market is declined by more than half after the period of financial crisis.

Table 4. The impact of the VIX return on the KOSPI index return in sub-periods

| | (1)<br>2002-2006 | (2)<br>2007-2011 | (3)<br>2012-2016 | (4)<br>2017-2021 |
|---|---|---|---|---|
| Constant | 0.00225*<br>(1.79) | -0.00033<br>(-0.44) | -0.00249**<br>(-2.10) | -0.00034<br>(-0.64) |
| Volatility Index Return | -0.07989***<br>(-11.40) | -0.08316***<br>(-19.02) | -0.03728***<br>(-16.91) | -0.02663***<br>(-15.62) |
| ARCH Lag(1) | 0.13587***<br>(4.60) | 0.29803***<br>(7.25) | 0.03553***<br>(2.89) | 0.34770***<br>(8.57) |
| GARCH Lag(1) | 1.37334***<br>(8.98) | 0.71598***<br>(7.83) | 1.56046***<br>(4.99) | 0.48830***<br>(7.09) |
| ARCHM Sigma2 | -6.8870<br>(-1.12) | 4.24537<br>(1.23) | 48.60527**<br>(2.15) | 10.31288*<br>(1.91) |
| $Chi^2$ Test | 132.32*** | 361.88*** | 286.05*** | 245.26*** |
| N | 1,196 | 1,210 | 1,198 | 1,192 |

*Note.* The numbers in parentheses are heteroscedasticity-robust z-statistics. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Arguably, the time decaying impact of the VIX on KOSPI return represents the decreasing economic ties between Korean and the US over the sample period. Because more than 80% of Korean GDP relies on the foreign trade, the size of international trades have a great impact on Korean economy and its stock market as well. If the time decaying relation between VIX and KOSPI return is driven by the decreasing economic ties between the two countries, the proportion of trade to the US market has reduced over time.

Figure 1 shows the proportion of export and import of Korea to the US. In 2002, the proportion of export and import to the US market is 20.2% and 15.1%, respectively. The reliance on the US economy has gradually declined to 10.1% of the export proportion in 2011 and 8.1% of the import proportion in 2013. The declining reliance on the US economy market continues up until year 2013. However, the downward trend is reversed and then recovered to the 14.9% in the export proportion and 11.9% in the import proportion in year 2021. Therefore, it appears that the decline in the economic ties between Korean and the US provides partial explanation for the time-decaying impact of the VIX and KOSPI return.

Nevertheless, the coefficient on VIX continues to be negative and statistically significant in the later periods. Therefore, investors in the Korean stock market are able to implement a trading strategy that minimizes investment risk by referring to the movement of VIX, which is a signal of heightened volatility in the US stock market.

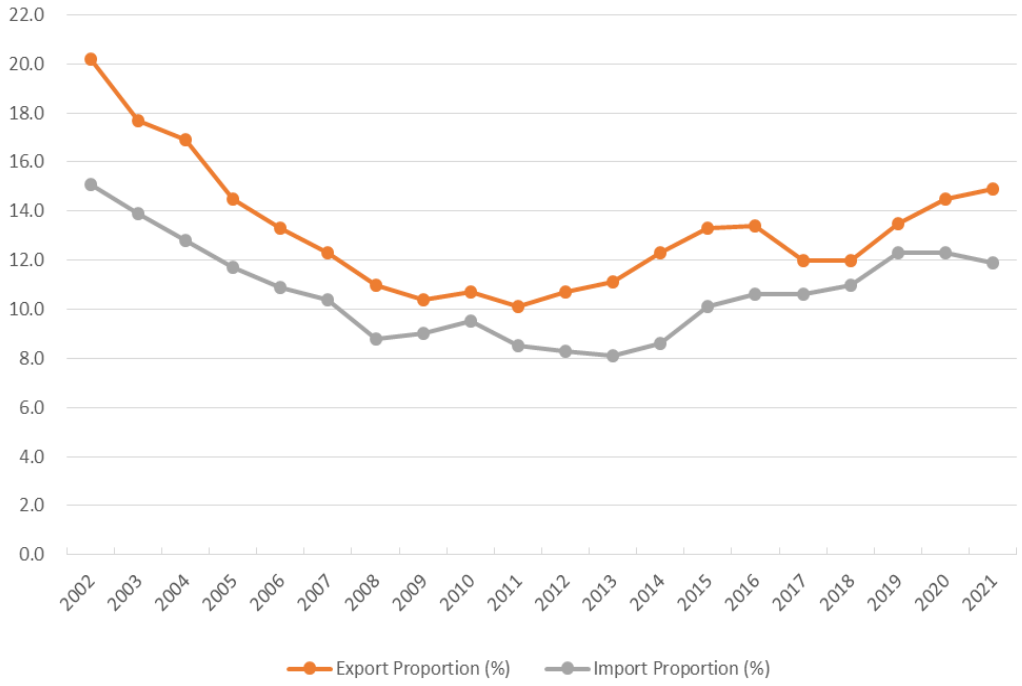


Figure 1. The proportion of the export and import to the US from year 2002 to 2022

*Note.* The numbers in the y-axis indicate the proportion of the export and import of Korean economy to the US.

## 5. Conclusion

This study examines the spillover effect of the volatility index on the stock return in the Korean stock market. VIX represents investors' prediction about the stock market volatility in the future. When VIX rises, investors sell stocks in fear that the volatility of the stock market increases in the future, and thus the stock price falls. Understanding the influence of the VIX on the Korean stock market is essential for investors in the Korean stock market to capture trading timing and reduce investment risk. Existing research mainly analyzed the synchronization of stock returns and, separately, the spillover of volatility between the US and Korean markets. The VIX has an advantage of being easy to understand as a direct measure of volatility in the stock market.

The main findings of the paper are as follows. The VIX return at time t-1 is negatively associated with the KOSPI return at time t. This implies that the volatility of the US stock market spills over to the Korean stock market. The influence of the VIX return on the KOSPI return has significantly reduced in the later period after the financial crisis. Nevertheless, the negative relation between the VIX return and the KOSPI return is persistent throughout the sample period, suggesting that the VIX continues to deliver an important information for investors in the Korean stock market to minimize investment risk in shaping their investment strategies. It is noteworthy that future research incorporating more international stock markets in the analysis will provide valuable insight to better understand the relative importance of

the US market's influence on the Korean market compared to other major markets.

**Competing interests**

Not applicable.

**Informed consent**

Obtained.

**Ethics approval**

The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

**Provenance and peer review**

Not commissioned; externally double-blind peer reviewed.

**Data availability statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**Data sharing statement**

No additional data are available.

**Open access**



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