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Bad and Good Asymmetric Volatility Spillover Connectedness Between the Exchange Rate and Stock Market of Major Asian Countries

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ABSTRACT

The aim of this study is to investigate the relationship between the spillover of exchange rate volatility and the Asian stock market, focusing on China, Japan, South Korea and India after the 1997-1998 currency crisis. Weekly returns (20 years) from 1999 to 2018 were used for this analysis. The EGARCH model is used to identify the asymmetric links between the two financial markets. The analysis showed that any change in the stock market has a major impact on the currency market. However, some shifts in the currency market have a smaller impact on the stock market. Exchange rate volatility tends to be higher when negative (bad news) innovation is compared to positive (good news) innovation for all but China. Such analysis is crucial for investors in developing a good investment portfolio and assessing risk in a safe and effective way.
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INTRODUCTION

The relationship between exchange rates and stock prices has been studied by many academics and professionals as it plays a very important role in the global economy. It is well known that the stock market and the foreign exchange market are strongly interrelated. Any fluctuation in the exchange rate can affect the volatility of stock prices across foreign investment portfolios. The research results are ambiguous as to whether the stock market price precedes the exchange rate or vice versa.

The most important factor of such an approach lies in the following logical conclusion. The downward movements in share prices led to a decline in investors' wealth. According to intuitive logic, this could lead to a lower demand for money by ensuring lower interest rates. The movements of capital flows and international portfolio capital seem to be influenced by the volatility movements of the stock price, as Efuntade and Efuntade (2023) and Reboredo et al. (2016) point out. Capital outflows tend to be higher when interest rates are low. Changes in equity markets are associated with capital movements and currency movements could be associated with trade flows. As the equity market is more integrated due to exchange rate changes and price movements, capital flows rather than current account imbalances are reflected. There is no doubt that a portfolio manager's profits in an investment portfolio are influenced by the ability to capitalise on the opportunities presented by these two important elements.

Several analysts have looked at the potential of the existing spillover of volatility or transmission between exchange rates and the stock market. Analysing the relationship between volatility spillovers between financial instruments helps to understand the transmission of information from exchange rates to stock prices or vice versa. Chiang and Yang (2003) and He et al. (2020) have shown that a significant spillover effect can be observed between the US and stock markets worldwide. Similarly, So (2001) examines the relationship between the US dollar exchange rate and the spillover effect of interest rates. The empirical results suggest that the relationship between these variables is not linear. The dependence between these markets appears to exhibit a short-term dynamic relationship. Reboredo et al. (2016) show that spillovers are asymmetric, with downside risk being greater than upside risk. This study also shows that spillovers to and from the USD are higher compared to other currencies. Similarly, Barunik (2017) found that spillovers are transmitted in different magnitudes for the good and weak volatility sectors in the US, which change significantly over time. Market volatility appears to react significantly more to bad news than to good news. BenSaida and Abdaillah (2018) point out that research on several developing countries suggests that lateral spillovers are more pronounced in turbulent times.

Empirical evidence from Boburmirzo and Boburjon (2022) and Yang (2004) supports the changes in exchange rate changes have less impact on the stock market. In contrast, movements in stock prices have a large impact on the exchange rate. Theoretically, the continuity of these two factors can be found in any academic study, especially in the studies dealing with the Asian financial crisis from 1997 to 1999, which mainly affected Indonesia, South Korea and Thailand (Tabak, 2006). Bidirectional causal correlations between exchange rates and stock prices and currency changes were observed in Yang et al. (2014) using the causality test in quantiles for nine Asian countries. Huo and Ahmed (2017) and Tsai (2022) found that the spillover effect of volatility from China to Hong Kong becomes stronger. Empirically, the openness of equity markets in China to the world could improve market efficiency while enhancing leadership, influencing the risk rate and improving the performance of the Chinese mainland stock market. The study done by Hussain and Li (2018), on the other hand, shows the potential of diversification instead of a strong link between equity markets in Greater China. In general, many research studies empirically support the effect of asymmetric volatility spillovers. Exchange rate fluctuations have less influence on stock market shifts. In comparison, stock price fluctuations showed a significant result.

However, in times of financial crises, such as the Asian financial crisis of 1997-1998, the behaviour of exchange rates can change dramatically, leading to a greater impact on stock market volatility. In such times, the increased uncertainty and economic instability can increase the sensitivity of equity markets to exchange rate fluctuations, as was seen in several countries affected by the crisis. In such scenarios, the asymmetric nature of volatility spillover effects could be exacerbated. Jeon et al. (2017), using daily stock return data at the company level and trade-weighted exchange rates from 1994 to 2013, found that exchange rate changes systematically affect the stock returns of individual companies in most Asian economies and that exchange rate shocks have a disproportionate impact on stock market volatility.

Volatility between financial markets and the international transmission of returns are also increasing due to the integration of financial markets and economic globalisation. Asia's leading countries such as Japan, China, India and South Korea have grown economically compared to the other Asian countries, which indirectly proves that these countries have excellent stock market and foreign exchange quality. The rapid growth of the Asian market proves that the Asian countries involved in the 1997 financial crisis have not been prevented from developing economically. The interdependence between these countries is increasing, especially between China, Japan and South Korea due to financial integration and the growing economy (Zhang et al., 2020). In particular, this connection brings benefits to China in the form of lower capital costs and capital inflows, enabling it to be one of the powerful countries in the world.

In this study, the relationships were analysed using the EGARCH model to explore the spillover effects of exchange rate volatility and stock prices in major Asian countries. The empirical evidence obtained from this study will help to explain short-term movements and the transmission of uncertainty between these markets. This study aims to fill the gap in the literature by investigating the relationship between exchange rates and stock markets through understanding asymmetric volatility spillovers and short-term value interactions for major Asian countries. Regarding the impact of volatility spillovers between currency and equity markets on the Asian financial market in particular, the information gained will contribute to better decision making for international portfolio managers, policy makers and multinational corporations.

The relationship between exchange rates and stock prices has been extensively studied due to its significant role in the global economy. However, most of the focus has been on symmetric volatility spillovers, while little attention has been paid to the asymmetric nature of these spillovers. This study aims to fill this gap by examining the asymmetric volatility spillover relationships between the exchange rate and the stock market of major Asian countries, particularly China, Japan, South Korea and India.

Several studies have examined the volatility spillovers between exchange rates and stock markets, but few have addressed the asymmetric effects of these spillovers. For example, Chiang and Yang (2003) and So (2001) highlighted the significant spillover effects between the US stock market and exchange rates. However, the potential for asymmetric spillover effects, where negative news could have a greater impact than positive news, has not yet been sufficiently explored in the context of Asian markets.

Despite the extensive research on volatility spillovers, there is a notable gap in understanding how asymmetries in these spillovers manifest themselves in major Asian economies. This study aims to fill this gap by employing the EGARCH model to capture the asymmetric volatility spillovers between the stock markets and exchange rates of China, Japan, South Korea and India.

Understanding the asymmetric volatility spillover is important for several reasons. First, it provides investors with deeper insights into risk management and portfolio diversification strategies, particularly in the context of the major Asian economies that play an important role in global financial markets. Second, policy makers can benefit from this knowledge to develop more effective economic policies that take into account the asymmetric effects of market shocks. Finally, this study contributes to academic literature by providing a comprehensive analysis of volatility spillovers and emphasising the importance of considering asymmetries in financial market research.

This study will provide investors who want to build a good portfolio between the linkages in these countries with a deeper understanding of the two areas of the economy that are highly correlated and examine the role of the stock market and foreign exchange (Tsai, 2012). The insightful information gained will help them manage their portfolio more efficiently while ensuring profitability for investors (Dimitrova, 2005). Based on the asymmetries arising from these behaviours, an appropriate portfolio diversification strategy and risk assessment could be undertaken.

This section focuses on the introduction and the literature on volatility spillovers. The following section describes the data and methods used in this study. Section 3 analyses the results of the study and its analytical findings. A summary of the study and general remarks can be found in section 4.

DATA AND RESEARCH METHODOLOGY

Data

The data for this study comes from Investing.com, a respected and widely used provider of financial data. The data set includes weekly closing prices, highs, lows and open prices for the major stock indices of four selected Asian countries: China, Japan, India and South Korea. These countries were selected due to their significant GDP growth in 2018, which makes them important players in the Asian financial markets. The equity indices analysed include the Shanghai Composite for China, the Nikkei 225 for Japan, the BSE SENSEX 30 for India and the KOSPI for South Korea. In addition, the foreign exchange data consists of the respective exchange rates of the currencies of these countries against the US dollar: Yuan, Yen, Rupee and Won.

The study covers a 20-year period from 1 January 1999 to 31 December 2018 and offers a comprehensive data set with approximately 1,040 observations per variable. This long period is crucial for capturing the long-term dynamics and volatility spillovers between equity markets and exchange rates and allows the study to observe patterns and structural changes across different economic cycles. The choice of weekly data rather than daily or monthly data strikes a balance between capturing relevant market movements and reducing noise from short-term fluctuations, ensuring that the analysis reflects meaningful trends without being skewed by daily volatility.

Although the data period ends in 2018, before the outbreak of the COVID-19 pandemic, this period is still highly relevant for several reasons. Firstly, the period includes major global economic events that have shaped the current financial landscape, such as the aftermath of the 1997 Asian financial crisis, the 2007-2008 global financial crisis and the European debt crisis. These events had a profound impact on the volatility and interconnectedness of global financial markets, particularly in Asia. By including these critical periods, the study captures a range of market conditions, from extreme volatility during the crises to more stable periods, providing robust insights into the behaviour of equity markets and exchange rates under different conditions.

The exclusion of data from the period of the COVID-19 pandemic is intentional, as the pandemic represents an unprecedented global shock with unique characteristics that could distort the analysis of long-term trends. By focusing on the pre-pandemic period, the study ensures that the results reflect more typical market dynamics that are likely to be more relevant for understanding the underlying mechanisms of volatility spillovers in the absence of exceptional disruptions.

Data preparation involved rigorous steps to ensure the quality and consistency of the data. All missing or erroneous entries were filtered out to avoid inaccuracies in the analysis. In addition, daily prices were converted into weekly prices by using the closing price of the last trading day of each week. This approach not only smoothes out short-term fluctuations, but also meets the study's objective of analysing medium-term volatility spillovers without the noise associated with daily price movements.

Overall, the chosen data period is adequate and suitable for the objectives of the study. It provides a rich data set that covers major economic events and offers insights into the volatility dynamics between the stock markets and exchange rates of major Asian countries before the pandemic. This approach allows the study to contribute valuable insights to the literature on financial market interconnectedness and volatility spillovers, while setting the stage for future research that could use post-pandemic data for comparison. The data conversion rates are calculated using the following equation:

$$R_{i,t} = 100\left[ln\left({}^{P_{i,t}}\big/_{P_{i,t-1}}\right)\right] \quad (1)$$

$P_{i,t}$ is the closing price for market i ($i = 1, 2$ where $i = 1$ is for the stock market and $i = 2$ for the exchange rate) for time t.

Methodology

In this study, employed the Vector Autoregressive (VAR) model was used to capture the short-term dynamic relationships between stock prices and exchange rates in the selected Asian countries. The VAR model is particularly suitable for analysing the interdependencies between several time series variables. It makes it possible to analyse how a change in one variable, e.g. share prices, influences another, e.g. exchange rates, over time.

$$R_{i,t} = \beta_{i,0} + \sum_{j=1}^{2} \beta_{ij,t-1}R_{j,t-1} + \sum_{j=1}^{2} \beta_{ij,t-2}R_{j,t-2} + \varepsilon_{i,t} \quad (2)$$

Referring in the above model, $\beta_{i,0}$, $\beta_{ij,t-1}$ and $\beta_{ij,t-2}$ are the parameters while $\varepsilon_{i,t}$ is residual to be estimated. To be specific, the information in the market i is part of the information set in the information set in the market j which can be used by the stock market and foreign exchange. As such, the coefficient $\beta_{i,j}$ for $i \neq j$ could be associate with the extent of the price (mean) spillover in the market or the accuracy of pricing information is accurate if statistically significant.

To ensure the validity of the VAR model, it is crucial that the data used in the analysis are stationary, i.e. that their statistical properties, such as mean and variance, do not change over time. Non-stationary data can lead to false results where the relationships identified by the model are misleading or incorrect. To counteract this, the Phillips-Perron test was employed to test stationarity. The Phillips-Perron test is a robust method to test whether a time series has a unit root, which would indicate non-stationarity. By testing the null hypothesis that a unit root is present in the data, this test helps to determine whether the time series data is stable over time. If the null hypothesis is rejected, this indicates that the data is stationary, which allows for the appropriate application of the VAR model.

Once stationarity was confirmed, the next step was to analyse whether there is a long-term equilibrium relationship between the variables—, i.e. whether share prices and exchange rates are cointegrated. Co-integration means that although the individual time series may not be stationary, their linear combination is stationary, which indicates a stable long-term relationship between them. The Johansen test was used for this purpose. The Johansen test is a powerful method for testing cointegration in a multivariate context and allows the identification of multiple cointegrating relationships. This test examines the rank of the cointegration matrix to determine the number of cointegrating vectors that exist between the variables, if any. If the test indicates the presence of cointegration, this suggests that the variables have a long-run equilibrium relationship, justifying the use of the VAR model with additional error correction terms to capture both the short-run dynamics and the long-run relationships.

In addition to these tests, skewness and kurtosis were assessed using the t-statistic test to determine the distributional properties of the data, in particular its symmetry and the presence of outliers. The Ljung-Box (LB) and Ljung-Box squared (LB2) tests were employed to determine the presence of autocorrelation in the residuals, which may indicate model misspecification if it is significant. These tests, based on a chi-squared distribution with 10 degrees of freedom, provide information on the adequacy of the model by checking whether the residuals are independent over time. Finally, the Kolmogorov-Smirnov test was performed to compare the data with a normal distribution and to further verify the appropriateness of the statistical methods used. By conducting these tests, the study ensures that the data is adequately prepared for the VAR model and allows for a reliable analysis of the asymmetric volatility spillover effects between stock prices and exchange rates in the major Asian economies.

Table 1 shows the behaviour of the data using descriptive statistics. The mean value shows that the weekly rate of change is not too far from zero. The skewness values show that the data measure for each series is negatively skewed and highly leptokurtic. Each series is statistically rejected based on the 5 per cent significance level of Kolmogorov-Smirnov normality. The Ljung-Box statistics calculate up to 10 lags for both the rate of change and the squared rate of change of the series. The values indicate the presence of non-linear and linear dependencies in the data. These features indicate the presence of market inefficiency and autoregressive conditional heteroscedasticity in the series.

Table 1 Descriptive statistics

Panel A: Stock Market	**China**	**Japan**	**South Korea**	**India**
Mean (μ)	0.0754	0.0339	0.1119	0.2360
Standard deviation (σ)	3.3522	3.0079	3.4258	3.1797
Skewness (S)	-0.2030	-1.0625	-0.5190	-0.3884
Kurtosis (K)	5.6478	10.619	7.5321	6.1316
Kolmogorov-Smirnov (D)	0.2420*	0.2521*	0.2444*	0.2667*
LB (10)	24.45*	5.06	12.66	22.46*
$LB^2(10)$	196.04*	71.859*	283.61*	204.9*
Panel B : Foreign Exchange				
Mean (μ)	-0.0179	-0.0047	-0.0056	0.0474
Standard deviation (σ)	0.2803	1.4355	1.3278	0.8409
Skewness (S)	1.0279	-0.2520	-0.1126	0.0850
Kurtosis (K)	22.2720	4.2255	12.2264	7.4426
Kolmogorov-Smirnov (D)	0.3304*	0.07783*	0.0322	0.14890*
LB (10)	110.31*	22.693*	45.763*	21.662*
$LB^2(10)$	54.7*	58.16*	826.7*	270.21*

Note: *denote significant at 1% significance level.

Descriptive statistics have provided a wealth of information from tests to indicate the best lag length for the VAR model to be used in this study. Based on the white-noise property of the residuals and the parsimony principle, the model with two lag periods or VAR(2) was selected. Due to the ARCH effect, this is very clearly recognisable for both marketplaces. The Exponential GARCH (EGARCH) model by Nelson (1991) is employed to model the relationship of volatility spillover and to understand the asymmetric effect between the two markets.

Multivariate EGARCH

In this study, the Exponential Generalised Autoregressive Conditional Heteroskedasticity (EGARCH) model is used in a bivariate form to examine and evaluate volatility spillovers between the stock markets and exchange rates of major Asian countries. The EGARCH model is particularly well suited for this analysis as it allows the modelling of asymmetric effects in volatility. In particular, it can capture the phenomenon that negative and positive shocks have different effects on market volatility, a feature that is crucial for understanding the nuanced relationships between these financial markets. The conditional variance in the EGARCH model is represented by the following equation:

$$\sigma_{i,t}^2 = exp\left\{a_{i,0} + \sum_{j=1}^{2} a_{ij} f_j(z_{j,t-1}) + \gamma_i ln(\sigma_{i,t-1}^2)\right\} \; for\ i,j = 1,2 \tag{3}$$

$$f_j(z_{j,t-1}) = (|z_{j,t-1}| - E(|z_{j,t-1}|) + \delta_j z_{j,t-1}) \; for\ j = 1,2 \tag{4}$$

Constant γ_i seen in the equation (3) is continuous volatility and the unconditional variance value will be limited if it is $\gamma_i < 1$. Equation (3) shows the conditional variance process to ensure that the number of lag and standard innovations between market i and j to capture the asymmetric effect on the volatility of the market of i. The value a_{ij} $i \neq j$ is the important coefficient as it will show the effect of volatility spillover. To be specific, if a_{12} it significantly differs from the value of zero, then the volatility of stock market price will overflow the stock price. The asymmetric nature where $z_{j,t-1}$ referring to the equation (4) is the standardized residual at time $t-1$, which can also known as ${\varepsilon_{j,t-1}}/{\sigma_{j,t-1}}$ and $E(|z_{j,t-1}|)$ are absolute expected values for $z_{j,t-1}$.

The parameter, δ_j is crucial for determining whether the effect of a shock (or an innovation) on volatility is asymmetric, i.e. whether negative shocks have a different effect than positive ones. The model is designed to show how volatility spills over from one market (e.g. the stock market) to another (e.g. the foreign exchange market). If the coefficient, a_{12} deviates significantly from zero, this indicates that the volatility on the equity market significantly influences the volatility on the foreign exchange market, which shows a spillover effect. This asymmetric effect is particularly important in financial markets, where bad news (negative shocks) often lead to higher volatility than good news (positive shocks). The model's ability to differentiate between these effects provides deeper insights into the dynamics of market behaviour.

Subsequently, the parameter value δ_j is interpreted as the asymmetric effect of stock market volatility using the following formula:

$$\begin{aligned} {\partial f_j(z_{j,t})}/{\partial z_{j,t}} &= 1 + \delta_j \; for\ z_j > 0, j = 1,2 \\ {\partial f_j(z_{j,t})}/{\partial z_{j,t}} &= -1 + \delta_j \; for\ z_j < 0, j = 1,2 \end{aligned} \tag{5}$$

When the value δ_j is negative, it means that the asymmetric effect is there and statistically significant. The size effect of innovation is measure in $\left(|z_{j,t-1}| - E(|z_{j,t-1}|)\right)$ and the corresponding sign effect $\partial z_{j,t-1}$. If a market has a negative value of δ_j, then has a positive value of a_{ij}, it means negative shock to the stock market and increase the volatility to the stock market more than a positive shock from both markets. Instead, it shows different effects, so we can see clearly the real asymmetric movement of the spillover mechanism.

In addition, the negative value of $z_{j,t-1}$ which is paired with the negative value δ_j will add to the sign effect. The importance of asymmetric effect elements or leveraged effects can be measured with the equation ${|-1 + \delta_i|}/{(1 + \delta_i)}$. This ratio intepret as the impact of differences from innovation from any market for the existing conditional variance. Therefore, the negative value of δ_i will increases the ratio. This shows that negative value of innovation can bring more impact on conditional volatility than negative innovation. In other words, the unexpected bad news which is negative innovations will have a greater impact than the good news which is positive innovations on the existing conditional volatility.

The residual in equation (2) is estimated to follow the normality behaviour and the specification of the conditional covariance previously considered as a constant correlation coefficient. The interpretation should be based on the fact that they measure contemporaneous relatedness. This simply means that the covariance is equal to the value of the standard deviation, as shown in the equation below:

$$\varepsilon_{i,t}|I_{t-1}N(0,H_t|I_{t-1}), H_t = \begin{bmatrix} \sigma_{1,t}^2 & \sigma_{12,t} \\ \sigma_{21,t} & \sigma_{2,t}^2 \end{bmatrix} for\ i,j = 1,2 \quad (6)$$

$$\sigma_{ij,t} = \rho_{ij}\sigma_{i,t}\sigma_{j,t}\ for\ i,j = 1,2\ and\ i \neq j \quad (7)$$

H_t is the conditional variance-covariance matrix at time t and the value of I_{t-1} is the information set at time period $t-1$. The number of parameters to be estimated could be reduced by the specification and makes the estimation easier. Following the normality assumptions, the model is estimated using Quasi-Maximum Likelihood Estimation (QMLE), which is particularly effective in dealing with non-normality in the residuals. In this method, the log-likelihood function given by is optimised:

$$L(\theta) = -\left(\frac{1}{2}\right)(NT)\ln(2\pi) - \left(\frac{1}{2}\right)\sum_{t-1}^{T}(ln|H_t| + \varepsilon_t H_t^{-1}\varepsilon_t) \quad (8)$$

N is the number of the equation, two for this study, T is the number of observations and θ is the representative of 1x21 vector estimation of parameters. QMLE is robust to deviations from normality and ensures that the model estimates are reliable even if the assumption of normality is violated (Bollerslev and Woolridge, 1992). The method is consistent with the normal distribution constraint when the mean and conditional variance are specified. The robust standard errors are measured considering the existing non-normality of the residuals. This robustness is crucial to capture the true nature of volatility spillovers and their asymmetric effects in the analysed markets. To summaries, the detailed treatment of asymmetric volatility by the EGARCH model combined with the robust estimation methods allows this study to provide deep insights into the complex volatility dynamics between the equity and foreign exchange markets of major Asian economies.

RESULTS AND DISCUSSION

Descriptive Statistics

Details of the descriptive statistics can be found in Table 1. The mean value of the individual markets is consistent and positive for all stock markets. However, the value of the foreign exchange market is consistently negative with the exception of India. The Indian foreign exchange market has a positive mean as India is the second fastest growing country in 20 years after China and is one of those that survived the 2008-2009 global financial crisis (Bose, 2019).

The same pattern can be observed for the stock market, which is consistent for standard deviation. The standard deviation indicates the dispersion of the overall data and is usually associated with volatility. The higher the standard deviation, the more spread out the data is with the mean, which is normally associated with a higher variance. The values are between three, which could indicate that the returns for the stock market are quite volatile. In contrast, the pattern of the foreign exchange market varies but is still lower than three. The standard deviation value of the yuan exchange rate is 0.2803, which is lower than other countries, indicating that China has a lower probability of volatility than other countries.

In terms of skewness, the values in both markets do not show the same pattern, except in the countries that are consistent, which implies a positive value for the stock market and the exchange rate. Unlike India, the skewness value of the stock market is negative but the exchange rate is positive. The positive or negative skewness values indicate the overall pattern of the data, whether it is skewed to the right or left. With kurtosis, all data have a leptokurtic character, as the values for all data are positive. This means that the position of the data outliers is more extreme than in the normal distribution and can therefore be described as a leptokurtic distribution.

Kolmogorov Smirnov is performed to test the normality of the individual data. The value of the Kolmogorov-Smirnov statistical test indicates that the individual series are not normal. This is consistent with previous literature which shows that the stock market and currency rarely follow a normal distribution. Finally, the Ljung-Box test is a test that specifically examines the randomness of each lag and was set at 10 lags for this study. The randomness of the individual data was significant, especially for the squared Ljung-Box.

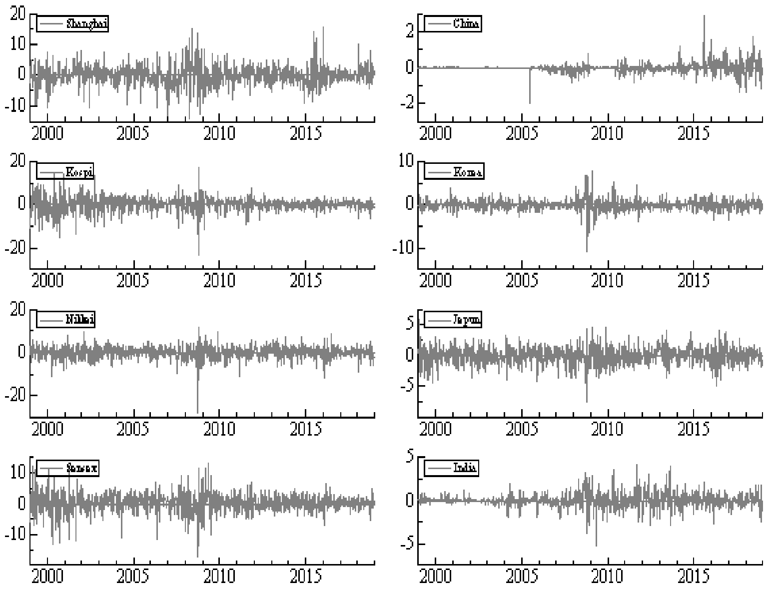

Figure 1 Pattern of return rate of stock market and foreign exchange market

Stationarity and Cointegration Tests

Before applying the VAR model, it must be ensured that the data used is stable and that there is no cointegration factor between the stock market and the currency in each country. If the data contains a cointegration element, the VAR model should contain error values, which should be avoided in this study. To perform the stationarity test, the study uses the Phillips-Perron test to test for autocorrelation and heteroscedasticity. The Johansen test is used for the co-integration test. Based on the results in Table 2, the Phillips-Perron test for stationary data shows that the data is robust at a number of levels either with or without a pattern for significance at the 1% level. This means that the data used is significant at the level of the series. The series is therefore I(0).

The cointegration test is no longer required as the data is a station. The Johansen cointegration test is performed on a data series that is not stationed at the series level, but at the first difference. If the data is a station at the series level, then there is no cointegration between the data (Engle et al., 2007). Therefore, the data in this study do not show long-term relationships. Therefore, the VAR equation in equation (2) is accurate and does not require the involving of the ε_{it} error.

Table 2 Phillips-Perron stationary test

Country	**Series Level**	
	No Pattern	**With Pattern**
Panel A: Stock Market		
China	-30.3905*	-30.3893*
Japan	-32.6936*	-32.6965*
South Korea	-34.6121*	-34.6084*
India	-31.9915*	-31.9774*
Panel B: Foreign Exchange Rate		
China	-29.3879*	-29.4122*
Japan	-34.4904*	-34.4817*
South Korea	-29.5322*	-29.5186*
India	-29.2597*	-29.2603*

Note: * Denotes significant at 1% significance level.

Results of Multivariate EGARCH

The maximum expected values of the log-likelihood can be seen in Table 2. The EGARCH Multivariate model is used to capture the asymmetric spillover of volatility between equities and foreign exchange. In the first moment, there was a significant spillover from the stock market to the Japanese and South Korean currencies. When the stock price rises dramatically, the value of the currency falls. This also means that when the stock price falls, the value of the currency rises. Since the studies use weekly data, this means that any rise or fall will take effect in the next week (Yang, 2004). For example, if Japan's share price rises this week, it means that the value of the currency will fall next week. This short-term effect is particularly important for international investors who pursue short-term strategies. According to Yang (2004), this is due to the rapid economic growth of both countries. This is supported by the International Monetary Fund (2018), which states that Japan and South Korea are technologically advanced countries, including robotics, smartphones, etc. The development of global technologies in Japan and South Korea is fueling economic activity between the countries.

Next, there is a spillover of uncertainty for the currency market in China's and India's share prices. This means that any rise in the currency results in a fall in the stock market and vice versa. In this case, short-term investments are extremely unsuitable as they will lead to losses. In the long term, this is not a problem, especially for the import and export markets. China and India are known for their import and export markets. China exports natural resources such as aluminium, charcoal, copper and tin, while India exports much of its oil, gold, diamonds and vehicles.

It seems that China, Japan and South Korea have shown the relations of the spillover of uncertainty from the stock market to the foreign exchange market for the second moment of dependence. The value of the foreign exchange market can be seen in Table 3. Since the value of the stock market is insignificant, there is no clear indication that the foreign exchange market has not spilled over to the stock market. More specifically, the movement of the forex market depends on the volatility of the asymmetric market. This also means that any unfavourable equity innovation for China, Japan and South Korea would have an amplified effect on the conditional performance of the foreign exchange market.

In Table 3, diagnostic tests are performed for the multivariate EGARCH model, which is essentially a good model for describing the dynamic relationship between two variables. The Ljung-Box test shows no significant test, which means that there is no linear and non-linear standard deviation. The Jarque-Bera result, a test for univariate normality for all stock markets and foreign exchange for all countries, is rejected. The sign bias test, a test for deviation, shows no significant value, except for the sign bias test for the Sensex stock market in India. The non-significance of the other data in the sign bias test shows no sign of asymmetry in the deviation. This test shows that the EGARCH model is better at modelling asymmetric volatility than the regular GARCH model, but not for the Sensex stock market as there are probably more appropriate models for this market's data.

Table 3 Parameter estimated of EGARCH model

Parameter	China		Japan		South Korea		India	
	Stock	**Foreign Exchange**	**Stock**	**Foreign Exchange**	**Stock**	**Foreign Exchange**	**Stock**	**Foreign Exchange**
$\beta_{i,0}$	0.0413^{**}	0.00003	0.1122	-0.0147	0.0084^{**}	-0.0086	0.2012	0.0224^{**}
$\beta_{ii,t-1}$	0.05300	-0.0001	-0.0869	0.04092	-0.1103	-0.1110^{**}	0.0250	-0.0402
$\beta_{ii,t-2}$	0.07939	0.00011	-0.0195	-0.0027^{**}	0.08310	0.0124^{**}	-0.0161	0.00844
$\beta_{ij,t-1}$	-0.0064^{***}	0.1064	0.0565^{**}	-0.2721	0.00182	-0.0674^{***}	-0.0883	0.0701^{**}
$\beta_{ij,t-2}$	-0.018^{*}	-0.0029	0.00487	0.03701	0.03311	0.0710	-0.0208	0.06929
$a_{i,0}$	0.0254^{***}	0.0662^{***}	0.2075^{***}	0.6895^{***}	0.0290^{***}	0.2149^{***}	0.0300^{***}	0.7218^{***}
γ_i	0.954^{***}	0.9798^{***}	0.9136^{***}	0.8737^{***}	0.9657^{***}	0.9515^{***}	0.9480^{***}	0.9894^{***}
$a_{i,j}$	-0.0030	0.2327^{***}	-0.2223	0.0268^{***}	-0.1126	0.1006^{**}	-0.0642	0.02774
$a_{i,i}$	0.2754^{***}	0.1318^{***}	0.2859^{***}	0.0835^{***}	0.4131^{***}	0.2555^{***}	0.2241^{***}	0.3613^{***}
δ_i	-0.3530^{***}	-0.409^{*}	-0.2723^{***}	-0.2295^{**}	-0.343^{*}	-0.3618^{***}	-0.365^{***}	-0.3518^{***}
ρ	0.02095	-	-0.020^{*}	-	-0.0777	-	-0.0457	
LB(10)	21.84	48.87	4.243	16.19	6.895	12.51	13.11	38.56
LB2(10)	4.598	0.1304	7.013	4.594	1.665	7.619	27.69	8.900
Jarque-Bera	104.4^{***}	7609^{***}	77.000^{***}	12.22^{***}	3049^{***}	94.49^{***}	244.9^{***}	546.3^{***}
SB	1.064	0.4437	1.194	0.9949	1.068	0.3334	1.856^{**}	0.4034
NSB	0.5911	0.5021	0.6337	0.3429	0.2779	0.6021	0.4516	0.4162
PSB	0.2930	0.1167	0.6346	0.2651	0.5042	0.8171	1.307	0.1803
Joint Test	3.702	0.2955	1.440	1.270	0.2956	1.844	13.31^{***}	0.3627

Note: *, ** and *** denote significance at 10%, 5% and 1%.

Volatility Persistence and Asymmetric Volatility Spillover Effect

The γ_i value is a value that represents the volatility persistence (Yang, 2014). To see the degree of volatility persistence for the next 14 weeks, the effect of the volatility shock can be referred at $\ln(0.5) / \ln(\gamma_i)$, which is based on the half-life of a shock. Table 4 at panel B shows the degree of volatility persistence for the stock market and foreign exchange for each country. All values are consistent, but an interesting observation could be seen at the foreign exchange market of China and India which is seen to be more affected than volatility shock.

Panel B in Table 4 demonstrates the degree of volatility asymmetric impacts from positive and negative innovations. The δ_i value means that the effect of volatility and the appropriate explanation to indicate the meaning of positive and negative innovations is good or bad news. Each value shown is the coefficient for the indicator of how much negative effect compared to positive effect, where the equation of effect is $|-1+\delta_i| / (1+\delta_i)$. As can be seen in the South Korean stock market, the effect on the volatility of negative innovation is twice the impact of positive innovation, similarly concerning the stock market and India's foreign exchange.

Table 4 Degree of Volatility Persistence

	China	Japan	South Korea	India
Panel A: Degree of Volatility Persistence				
Stock	14.6224	7.6735	19.8657	12.9801
Foreign Exchange	67.4158	5.1353	13.9305	65.0441
Panel B: Degree of Volatility Asymmetric Impacts				
Stock	0.9323	1.7484	2.0441	2.1486
Foreign Exchange	2.3852	1.5956	1.1318	2.0855

The findings of this study further explain how the positive and negative impacts of connectedness on the stability of exchange markets in the coming weeks would be affected. This value is crucial for foreign investors to plan appropriate strategies in managing the portfolio. Based on Table 4, we can see all the increasing values of volatility in percentage when innovations occur in the stock market. Positive innovation is one percent increase in stock market and negative innovation is one percent decrease in the stock market. The values shown in Table 4 are generated using the equation given by Yang (2014) which is $a_{i,j}(1+\delta_i)$ for one percent increase and $a_{i,j}|-1+\delta_i|$ for one percent decrease. For example, for China, a one percent increase in stock market would have 0.2409 percent impact on the volatility of the foreign exchange market. The change percentage in volatility for each country has its pattern, which is the change percentage in volatility is higher when negative innovations occur. In other words, negative developments that reflect a one percent decrease in the stock market impact on the currency market more than a rise in the stock market of one percent. However, the trend varies marginally for China, since a one percent rise in the stock market has more effect on the foreign exchange volatility percentage than a one percent decrease.

Table 5 Change Percentage in Volatility of Foreign Exchange Market

Innovation	China	Japan	South Korea	India
+1% in Stock Market	0.2409	0.0195	0.0661	0.0176
-1% in Stock Market	0.2246	0.0341	0.1351	0.0379

CONCLUSIONS

The financial markets of the major Asian economies, including China, Japan, South Korea and India, have developed rapidly and contributed significantly to the economic success of these countries. The aim of this study was to analyse the asymmetric volatility spillovers between the stock and foreign exchange markets of these countries using the Multivariate EGARCH model. The results confirm the existence of volatility spillovers, with negative innovations in the stock market generally leading to higher exchange rate volatility than positive innovations. This asymmetric relationship emphasises the importance of understanding the differential impact of market movements on volatility, which has important implications for investors and policy makers.

One of the key observations of this study is that negative innovations in the stock markets of Japan, South Korea and India - with the exception of China - lead to a greater increase in exchange rate volatility. This can be explained by several underlying mechanisms. First, negative news often triggers risk-averse behaviour among investors, leading to a flight to safety in which capital is reallocated from riskier assets such as equities to safer assets, including foreign currencies. This sudden reallocation increases the demand for foreign exchange, leading to increased volatility. The lack of a similar pattern in China can be attributed to the relatively controlled exchange rate regime and the significant influence of government policy, which can protect the foreign exchange market from the same level of volatility seen in more liberalised markets.

In addition, market sentiment and herd behaviour play an significant role in amplifying the impact of negative innovations. When investors react collectively to negative news by selling assets, the resulting market movements can create a feedback loop that amplifies volatility. This is particularly evident in Japan, South Korea and India, where market sentiment strongly influences exchange rate dynamics. However, the Chinese market may be less susceptible to such collective movements due to its unique market structure and significant government intervention, which could dampen the volatility response to negative innovations.

Furthermore, the economic and structural differences between China and the other countries in this study contribute to the different effects of negative innovation. China's exchange rate policy, characterised by tighter control and large foreign exchange reserves, provides stability against external shocks and reduces the sensitivity of its currency to domestic stock market fluctuations. This contrasts with the more flexible exchange rate systems in Japan, South Korea and India, where market forces play a greater role in determining exchange rate movements.

The practical implications of these findings are significant. For investors, understanding the asymmetric nature of volatility spillovers is essential for effective risk management and portfolio diversification. The study suggests that investors should pay close attention to negative market shocks, particularly in Japan, South Korea and India, where the impact on exchange rate volatility is more pronounced. This knowledge can feed into more sophisticated hedging strategies that consider the asymmetric risks associated with these markets.

To summarise, as Asian economies continue to grow and become more integrated into the global financial system, the interconnectedness between their equity and foreign exchange markets is likely to increase. The findings from this study provide valuable guidance for investors, policy makers and economic participants and emphasise the need to consider the asymmetric impact of market innovation in their decision-making processes.

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