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Do "meteor showers" matter more than "heat waves" in exchange rate volatility of Australia and some of its Asian trading partners?

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Abstract

This paper aims to examine the determination of volatility spillover across the markets of Australia, China, Japan, South Korea and also the United States as a result of the US financial crisis. By employing daily yen-US dollar data, volatility is measured using EGARCH-M (1, 1). It varies with time and is asymmetric, implying that the depreciation of the US dollar has greater impact on volatility than appreciation of the currency. The volatility spillover estimation is based on vector autoregressive model using seemingly unrelated regression. Moreover, Toda and Yamamoto Granger non-causality tests and impulse responses are employed. The results indicate that own past volatility, "heat waves", dominates in three out of five markets relative to the past volatility of the trading partners, "meteor showers", implying own volatility has greater role in own predictability.

Keywords: exchange rate volatility, trade, financial crisis and impulse responses.

JEL classification: E44 F31 G01

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1. Introduction

During its economic history, the world has seen several financial crises, ranging from minor to severe, depending on the magnitude of their impact. Among the earliest ones, Reinhart and Rogoff (2008a) reported five major crises which include the Spanish (1977), Norwegian (1987), Finnish (1991), Swedish (1991), Japanese (1992) and Mexican Peso (1994) crises. The most recent crises include the Asian financial crisis (1997-1998), Russian crisis (1998), Argentine crisis (2002) and U.S. crisis (2007-2009). What distinguishes these crises from one another rests on their origins, duration and the extent of their contagious effects. Although these crises varied significantly, they have one feature in common in that they made the exchange rate more volatile during the episodes of the crises. Relative to the crises mentioned earlier, the degree of the spread from the crises in the financial markets to the foreign exchange markets was highly pronounced during the U.S. financial crisis. While the other crises were restricted to more or less regional impact, the U.S. crisis had a global effect as has also been found in the study by Coudert et al., (2011).

Among its several global effects, the U.S financial crisis had manifested its impact on various policy changes around the globe which affected the decisions of foreign exchange market players. In general, exchange rates are more sensitive to the news from within and outside a given economy. This was very evident when the Federal Reserve announced various monetary policy changes to which several countries had to follow suit after the crisis. For example, there were frequent swings of the exchange rates following the news of interest rate cuts and rumors of the debate on whether or not to bail out the bankrupted companies, whether or not to inject more money into the economy and so on. This study seeks to examine the spillover effect of the exchange rate volatility as a result of the news related to the changes after the U.S. financial crisis. More specifically, it addresses the question whether previous foreign volatility generated from the news has greater impact than a market's own previous volatility which Engle et al., (1990) referred to as "meteor showers" versus "heat waves".

The remainder of the paper is organized as follows: the next section discusses the literature review, section 3 will address the methodology used in the study; Section 4 explains the data type and sources of the data; Section 5 reports the results, and Section 6 gives the conclusion.

2. Literature Review

Previous studies on the issue of "meteor showers" versus "heat waves" find two opposite outcomes. By examining whether news in the New York market can predict volatility in Tokyo several hours later, Engle et al., (1990) find evidence of "meteor showers", volatility spillover from one market to the other. Surprisingly, their studies find that "heat waves" are absent - volatility spillover from own volatility in the past.

Similarly, in their study of volatility spillover between euro-US dollar and US dollar-yen currency across five trading regions, Galagedera and Kitamura (2012) find in favor of "meteor showers" in the US dollar-yen data. In contrast to these studies, the study by Melvin and Melvin (2003) suggest "heat waves" are more important than "meteor showers". Likewise, Cai et al., (2008) indicate large own region spillover in their slightly different approach of similar study.

This research is different from the existing studies in two key aspects. First, it introduces unlagged information in the spillover model to capture market reaction and to determine to what extent unlagged information influences the spillover relative to lagged information. Second, it incorporates the Toda and Yamamoto (1995) procedure of Granger non-causality test to determine the direction of the spillover.

3. Methodology

To determine the direction of the spillover and also where it mainly comes from, first it is crucial to examine how the exchange rate volatility is measured. Among various methods of measuring the exchange rate volatility, this study adopts Exponential Generalized Autoregressive Conditional Hetroskedastic in mean; EGARCH-M (1, 1) for several reasons.

First, the distributions of all the exchange rate returns are leptokurtic with positive excess kurtosis. The fact that the returns are not normally distributed, employing standard deviation to capture volatility as opposed to EGARCH-M (1, 1) will result in biased and inconsistent estimation of the spillover.

Second, EGARCH-M (1, 1) allows to examine time varying and asymmetric effects of exchange rate returns in contrast to the realized volatility measured by the squared returns.

Third, in general, studies by Hu and Tsoukalas (1999) and Köksal (2009) show that EGARCH models out performed GARCH (1, 1) in out-of-sample forecasting. In particular, a study by Kaiser (1996) indicates that EGARCH-M (1, 1) has outperformed nine GARCH models in examining the volatility of the return on German stock. Furthermore, unlike GARCH, the variance equation in EGARCH is specified in logarithmic form and it does not impose non-negativity constraints on the parameters. Specifying in logarithmic form helps restrain the effects of outliers in the ultimate results of the estimation. Having discussed the reasons for adopting EGARCH-M (1, 1), the model can be specified as follows:

$$\varepsilon_{i,t} = \alpha_i + \theta_i log\sigma^2_{i,t} + u_{i,t} \tag{1}$$

$$log\sigma^2_{i,t} = \mu_i + \omega_i \frac{|u_{i,t-1}|}{\sqrt{\sigma^2_{i,t-1}}} + \varphi_i \frac{u_{i,t-1}}{\sqrt{\sigma^2_{i,t-1}}} + \delta_i log\sigma^2_{i,t-1} \tag{2}$$

Equations (1) and (2) represent the conditional mean and conditional variance respectively. It can be noted here that the conditional mean equation includes the variance of the exchange rate returns in logarithmic form, $log\sigma^2_{i,t}$, and makes it possible to examine the impact of volatility on the returns. $\varepsilon_{i,t}$ is the exchange rate return of country i at time t. The random error term for country i at time t is represented by $u_{i,t}$.

The coefficients of the constant term in the conditional mean and variance equations are denoted by α_i and μ_i respectively. While φ_i captures the asymmetric effect of the shocks to the exchange rate volatility, ω_i and δ_i are the parameters of ARCH and GARCH. The sum total of the two parameters indicates volatility persistence. θ_i denotes the coefficient of variance of the exchange rate returns for country i.

The spillover of the exchange rate volatility can be captured using different methods (see Dungey et al., 2005; Eichengreen et. al., 1996; Favero and Giavazzi, 2000; Bae et. al., 2003; and Hartman et. al., 2004). In this paper, to determine whether "meteor showers" matter more than "heat waves", first the volatility series for each country is collected from the model specified above. The series then was regressed on its own lagged volatility ($V_{i,t-1}$) together with the lagged volatilities of the trading countries ($V_{j,t-1}$) and with the dummy variables representing unlagged information as well as holidays (Z_t). The model can be specified as

$$V_i = \mu_i + \alpha_i V_{i,t-1} + \sum_{j \neq i} \alpha_j V_{j,t-1} + \beta_i Z_t + u_{i,t} \qquad (3)$$

Testing the hypothesis that either α_i or α_j is zero signify there are no "heat waves" or "meteor showers" effect respectively. It should be noted here that in estimating the model, time differences among the trading countries are considered. The selected Asian countries together with Australia share a similar time horizon with very minimal differences in their opening and closing trading hours. However, there are large time differences between the US and the remaining countries. To account for these differences, the current trading day information of Australia and the selected Asian countries are considered as past information in the determination of US exchange rate volatility spillover because the US ends the trading day.

Considering the autocorrelation effect, equation (3) is estimated as a system of five equation vector autoregressive model using seemingly unrelated regression (SUR). The advantage of SUR is that it provides efficient estimates even though the error terms are correlated across the equations.

The unlagged information are determined by the direction of the exchange rate returns. It is assumed that due to the contemporary development of information technology in media, the internet and other hardware and software, foreign exchange market participants are informed quickly. Accordingly, they adjust their decisions based on the information received and determine the directions of the returns on the exchange rates. In a given foreign exchange market, therefore, the impact of either positive or negative information is manifested in the form of positive and negative returns on the exchange rate respectively.

The impact of either positive or negative information remains for some time in the foreign exchange market unless replaced by new information. For this reason, the first positive or negative returns are considered as an indication of the effect of the arrival of new information and are given one in creating the dummy variable.

4. Data

To carry out the analysis, daily data ranging from August 2007 to December 2009 of five countries namely: Australia, China, Japan, South Korea and the US are used[1]. These countries are selected based on their trade relationships so as to determine to what extent their trade links influence the spillover of exchange rate volatility. To account for the yen-US dollar quote in each country outside the US and Japan, first data on both the exchange of the country's local currency to US dollar and of yen to local currency are collected. The data are gathered from

[1] It should noted here that due to data issue the New Zealand market is not included in the analysis.

the exchange rate section of the DataStream. The descriptive forms of the returns on the exchange rate data are presented in Table 1.

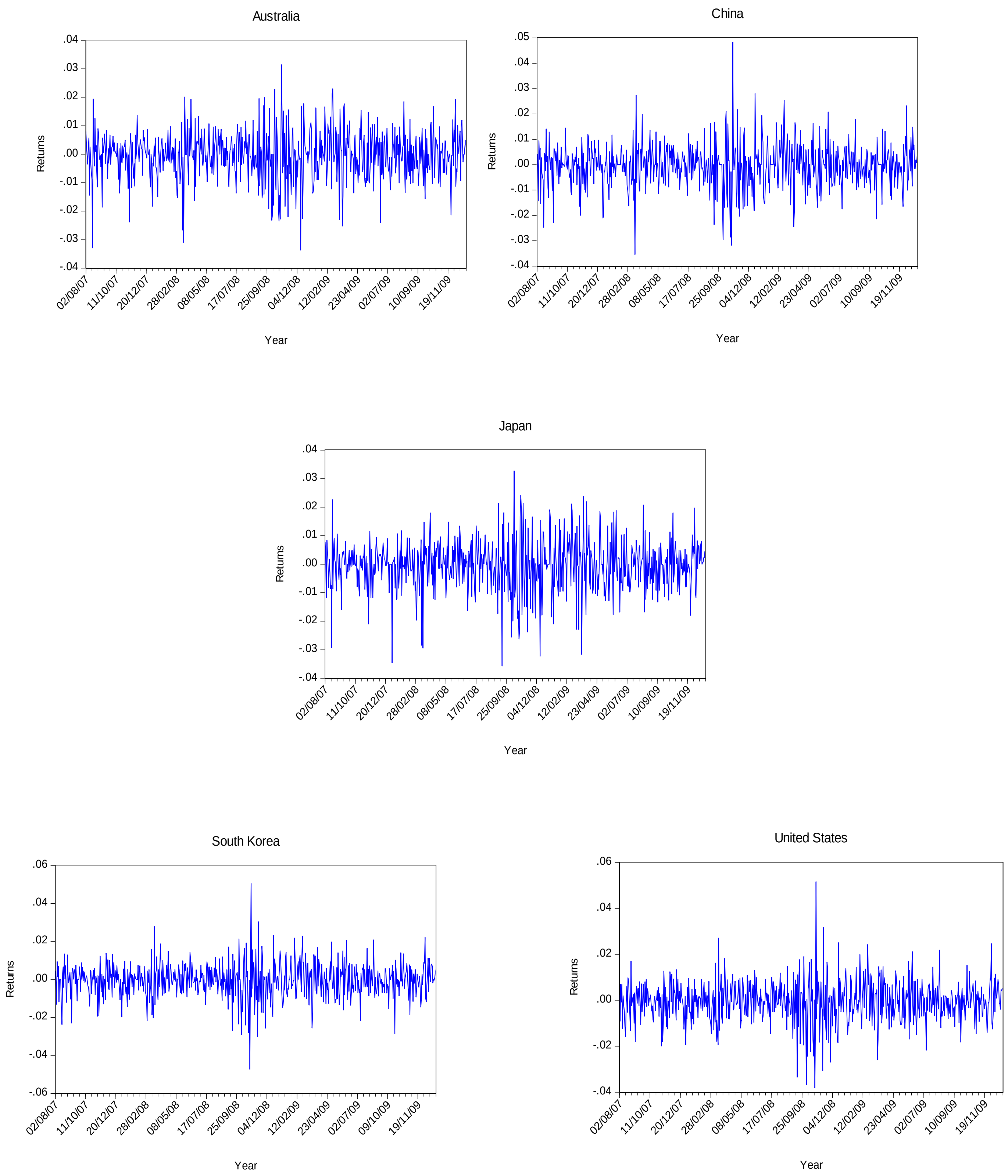
Table 1. Descriptive statistics of the returns on the exchange rate data

	Australia	China	Japan	South Korea	US
Mean	-0.000386	-0.000392	-0.000390	-0.000393	-0.000390
Maximum	0.031425	0.048291	0.032735	0.050462	0.051678
Minimum	-0.033702	-0.035408	-0.035699	-0.047384	-0.038126
Std. Dev.	0.008486	0.008590	0.008926	0.009092	0.008987
Skewness	-0.318339	0.002794	-0.364651	-0.138472	-0.015026
Kurtosis	4.309382	5.627097	4.624847	6.000301	5.911164
Jarque-Bera	55.73414	181.4564	83.39737	238.6890	222.8424
Observations	631	631	631	631	631

It can be seen from the table that the mean return is negative in all the selected countries with the US having the highest maximum return followed by South Korea. The results in the table also show that apart from the exchange rate returns in China, the returns in the remaining countries have negative skewness. The exchange rate returns in all the selected countries, however, have positive kurtosis with the highest kurtosis in the returns of the South Korea's yen-US dollar quote. The Jarque-Bera results of the returns collectively indicate that the returns are not normally distributed. The results of the standard deviation suggest that there is high volatility in the returns on yen-US dollar quote of the South Korean market followed by the US. Furthermore, the results of the standard deviation show that the Australian yen-US dollar quote shows least volatility followed by the quote in the Chinese foreign exchange market.

The movements of the exchange rate returns can further be examined from Figure 1. which plots these returns across the countries. The figure indicates that right after the financial crisis, towards August 2007, the markets in Australia and Japan demonstrated higher volatility than the rest. They remained higher until the second eruption of the crisis towards September 2008 which remarkably hit all the markets with relatively significant volatility in the US market. All the markets continued to demonstrate the movements in the returns after September 2008 with significant down turns in March 2009. In general, the figure shows that the fluctuations of the returns look wider in the Japanese market followed by the Australian and Chinese markets.

Figure 1. The exchange rate returns



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5. Empirical Results

As mentioned in the methodology section, exchange rate volatility is measured using EGARCH-M (1, 1). To ensure whether or not EGARCH-M (1, 1) is appropriate in capturing volatility, first an ARCH effect test is performed. The results of the test are reported in Table 2. The test statistics in the table suggest that the null hypothesis that there is no ARCH effect in the exchange rates quoted across the selected markets can be rejected. Thus, there is evidence of the ARCH effect in each series of the markets which supports the use of EGARCH-M.

Table 2. ARCH effect test results

Test Statistic	Australia	China	Japan	South Korea	United States
F statistic	12.1815***	3.1787*	7.2685***	46.4249***	4.4101**
	(0.0005)	(0.0751)	(0.0072)	(0.0000)	(0.0361)
Obs*R-squared	11.9878***	3.1728*	7.2082***	81.2444***	4.3933**
	(0.0005)	(0.0749)	(0.0073)	(0.0000)	(0.0361)

Note: the results in parentheses are the p values. ***significant at 1 percent. **significant at 5 percent.* significant at 10 percent.

After detecting the ARCH effect in the series, the lag length of the EGARCH-M is determined based on the ARCH LM test. To perform this procedure, first EGARCH-M (1, 1) is estimated for each series and then investigation is made whether there is an ARCH effect remained in the series. The results are reported in Table 3. It is evident from the table that the null hypothesis of no ARCH effect in the series can be accepted as the test statistic results are very low for all the rates quoted across the markets. Since the ARCH effect disappears from the series, there is no need of adding extra lags in the EGARCH-M to measure the exchange rate volatility of each market. The disappearance of the ARCH effect from each series after the estimation of EGARCH-M (1, 1) indicates that the volatility of each series can be captured well enough by EGARCH-M (1, 1).

Table 3. ARCH effect after EGARCH-M (1, 1) estimation

Test Statistic	Australia	China	Japan	South Korea	United States
F statistic	0.1398	0.0382	0.1220	0.2304	0.1116
	(0.7086)	(0.8451)	(0.7269)	(0.7942)	(0.7384)
Obs*R-squared	0.1402	0.0383	0.1224	0.4627	0.1119
	(0.7081)	(0.8448)	(0.7264)	(0.7934)	(0.7379)

Note: the results in parentheses are the p values.

The estimated results of EGARCH-M (1, 1) are reported in Table 4 and show that the coefficient of the variance of the exchange rate returns, θ, has a positive effect on the mean returns of the exchange rates across the markets. However, the test statics results indicate that apart from the returns in the Chinese market it has insignificant effect in all the markets. The ARCH and GARCH parameters denoted by ω and δ respectively are statistically significant at all levels for all the markets. While the ARCH value is higher in the Chinese market, the GARCH value is high in the Japanese market. Over all, the persistence of exchange rate volatility measured by the sum total of the ARCH and GARCH values is lower in the Chinese market than the rest. The shocks to the volatility in the remaining markets have a permanent effect as the sum total of the ARCH and GARCH coefficients exceeds one. This suggests that the conditional variances of the returns in these markets do not converge on constant unconditional variance in the long run.

The persistence of high volatility raises the concern as to whether there is a feedback by other markets once a shock strikes in one market. In other words, it raises the question whether or not the spillover from one market to another and the responses to this spillover are manifested through the persistence of the volatility across the markets. The asymmetric effect of the shocks on exchange rate volatility, which is captured by the parameter φ, is negative and statistically significant at 5 percent for the Chinese market and at all levels for the remaining markets. This indicates that there are leverage effects in all the markets in that negative news has a greater impact on the exchange rate volatility than an equal and opposite positive news.

Table 4. EGARCH-M (1,1) results across the markets

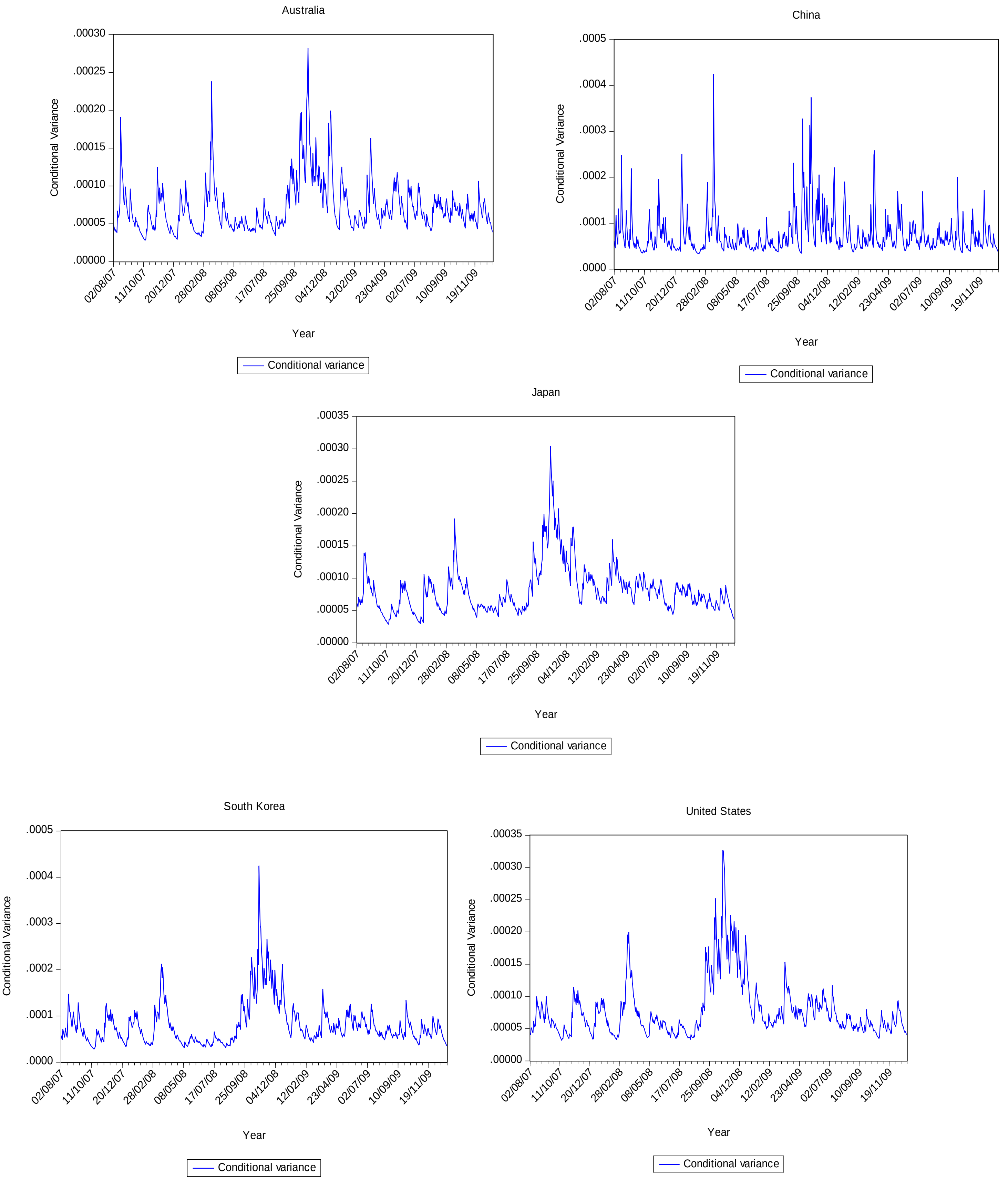
Parameters	Australia	China	Japan	South Korea	United States
θ	15.318	14.857*	2.533	14.687	14.149
	(0.1639)	(0.0995)	(0.7752)	(0.1170)	(0.1512)
ω	0.159***	0.291***	0.129***	0.138***	0.155***
	(0.0013	(0.0025)	(0.0075)	(0.0042)	(0.0014)
φ	-0.121***	-0.212***	-0.077**	-0.121***	-0.095***
	(0.0014)	(0.0032)	(0.0322)	(0.0006)	(0.0052)
δ	0.896***	0.691***	0.954***	0.937***	0.943***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
GED	1.396***	1.184***	1.100***	1.421***	1.555***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: the results in parentheses are the p values. ***significant at 1percent. **significant at 5 percent.* significant at 10 percent.

The negative results of the asymmetric effects can further be interpreted to mean that depreciation in the US dollar has a greater effect on the exchange rate volatility across the markets than appreciation of the dollar. It is clear from the table that the asymmetric effect is higher in the U.S market followed by the Japanese market. The results of the diagnostic test indicate that the errors of EGARCH-M (1, 1) for each series are not normally distributed. For this reason, generalized error distribution (GED) is employed in the estimation. The results of this parameter are reported in the table and are statistically significant at all levels for all the markets indicating that the model fits well to capture the exchange rate volatility and that the test statistic results are unbiased. The exchange rate volatility based on EGARCH-M (1, 1) is shown graphically in Figure 2.

It can be noted from the figure that during March 2008, there was a sharp rise in the conditional variance of the exchange rates in the Australian and Chinese markets relative to other markets. All the markets are marked by significant volatility towards the end of 2008, with remarkable increase in conditional variances during October 2008. Of all the markets, the South Korean market depicted higher conditional variance of the exchange rate during the specified period although it dies out there after. In March 2009, there was another hike in the conditional variances across the markets with the highest record in the Chinese market. In general, the rise and fall of the conditional variances at different periods in different markets, following one after the other and vice versa, suggest that the markets are not free from the spillover effect of the volatility. Whether or not this is the case is an empirical matter and is addressed in the next discussion.

<u>Figure 2. Volatility based on EGARCH-M (1, 1)</u>



5.1. The spillover across the markets

The analysis of the exchange rate volatility outlined above indicates traces of spillover across the markets. There is no doubt that the fundamental reason for the yen-US dollar volatility in the US market during the study period is the US financial crisis. However, the impact of the crisis did not remain confined to the US. Due to the link of the US financial and goods market with the rest of the markets, whatever happened in the US market was felt in the other markets. The point that needs to be addressed here is the extent to which changes in the US market affect other markets. Are the selected markets sensitive to their own volatility more than to the volatility of the US and the other selected trading partners once the crisis strikes? To what extent do trade relations matter in volatility spillover? Considering these questions, we estimate equation (3). The results of a country's own past volatility as well as that of other markets together with their p-values are reported in Table 5.

The results in Table 5 show that volatility in the US market has significant influence on the volatility of all selected markets at all levels of significance. Apart from the Japanese market, the remaining markets have insignificant effects on the US market. The significant impact of the US market on the rest and the insignificant impact of the rest on the US market imply that the latter has greater influence in the determination of the volatility of the yen-US dollar across the markets. The results further show that there is volatility spillover from the Australian market to the Chinese, Japanese and South Korean markets. Likewise, the volatility in the South Korean market spills over into the Australian, Chinese and Japanese markets. There is also volatility spillover from the Chinese and Japanese markets to the Australian and US markets respectively.

Table 5. Volatility spillover results

	Dependent Variables				
	Australia	**China**	**Japan**	**South Korea**	**United States**
Australia	0.738***	0.319***	0.072*	0.108***	0.053
	(0.0000)	(0.0007)	(0.0654)	(0.0061)	(0.3098)
China	0.069***	0.530***	0.015	0.002	0.005
	(0.0009)	(0.0000)	(0.3642)	(0.9006)	(0.8088)
Japan	0.039	-0.006	0.8001***	-0.032	0.157***
	(0.3423)	(0.9363)	(0.0000)	(0.3420)	(0.0005)
South Korea	-0.407***	-1.128***	-0.229***	0.190***	-0.039
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.4740)
United States	0.522***	1.263***	0.345***	0.770***	0.815***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
d_{UI}	0.000003***	0.000007***	0.000003***	0.0000004***	0.000001***
	(0.0000)	(0.0000)	(0.0005)	(0.5469)	(0.2714)
Adj. R^2	0.833	0.643	0.912	0.941	0.884

Note: the results in parentheses are the p values. ***significant at 1percent. **significant at 5 percent.* significant at 10 percent. The coefficients of the dummy variable for holidays are negative and statistically significant for the Chinese market, for the rest they are insignificant.

The volatility spillover from one market to another market discussed above gives evidence of "meteor showers" in the markets. However, the results indicate that the magnitude of own volatility is greater than that of other markets for all the markets apart from the Chinese and South Korean. The presence of significant own volatility suggests evidence of "heat waves" in the Australian, Japanese and US markets. This implies that the markets are more sensitive to their own past volatility generated from the news of the policy changes in either domestic or foreign markets than past volatility of the other markets. The results of volatility determination with respect to the US contrast with the findings by Engel et al., (1990) and Galagedera and Kitamura (2012) whereby "meteor showers" dominate in their study period. The difference in the findings of our study relative to that of Engel et al., (1990) might be partly explained by the difference in the sample periods. Their study was marked by the absence of the financial crisis originated from the US whereas this study's sample period comes after the US financial crisis. On the other hand, our findings concerning the dominance of "heat waves" in the US exchange rate volatility are in line with those of Melvin and Melvin (2003) and Cai et al., (2008). It can be noted from the results that trade relations are manifested in volatility spillover based on the demand for yen-US dollar currency in the markets. The volatility spillover from the Australian, South Korean and US markets to the Chinese and Japanese markets, for instance, shows trade relations between the latter and the former markets.

The coefficient of the exchange rate volatility resulting from unlagged information denoted by d_{ui} is positive across all the markets, indicating that volatility increases with the arrival of new information in the markets. The results are statistically significant in the Australian, Chinese and Japanese markets. The magnitude of the volatility due to unlagged information, however, is very low relative to the coefficients of other variables. This suggests that the markets react sluggishly to the arrival of new information and that lagged information has a stronger impact on the exchange rate volatility in the markets. Furthermore, the results suggest that despite the development of information technology that enhances the spread of the news on policy changes, by and large investors are cautious in their decisions which collectively determine the exchange rate volatility in the markets. The results could also imply that there might be conflicting new information arrivals which leave the majority of the participants in the market indifferent until clear evidence prevails in the market.

5.2. Toda and Yamamoto Granger non-causality of the spillovers

To determine whether there was a feedback from each market when the crises struck and whether there was a unique direction in the volatility spillover, the Toda and Yamamoto Granger non-causality test is applied. In the procedure, the lag length is determined by Schwarz Information Criteria first. Due to the presence of serial correlation in the residuals, however, the lag length is extended until the autocorrelation issue is resolved. The Chi square results and their equivalent p-values in parentheses are shown in Table 6. The results indicate that there is evidence of a causal relationship proceeding from the volatility in the US market to the Australian, Chinese, Japanese and South Korean markets. Likewise, the volatility in the Chinese market Granger causes the volatility in the Australian, Japanese, South Korean and the US markets.

Table 6. Toda and Yamamoto Granger non-causality test

	Dependent Variables				
	Australia	**China**	**Japan**	**South Korea**	**United States**
Australia		28.241* (0.0789)	48.366*** (0.0002)	32.678** (0.0262)	49.554*** (0.0002)
China	40.723*** (0.0026)		28.904* (0.0675)	40.182*** (0.0031)	66.988*** (0.0000)
Japan	23.853 (0.2019)	21.396 (0.3154)		38.585*** (0.0050)	30.343 (0.0476)
South Korea	33.124** (0.0233)	26.794 (0.1095)	36.734*** (0.0086)		77.414*** (0.0000)
United States	483.248*** (0.0000)	786.357*** (0.0000)	322.934*** (0.0000)	2651.932*** (0.0000)	

Note: the results in parentheses are the p values. ***significant at 1percent. **significant at 5 percent.* significant at 10 percent.

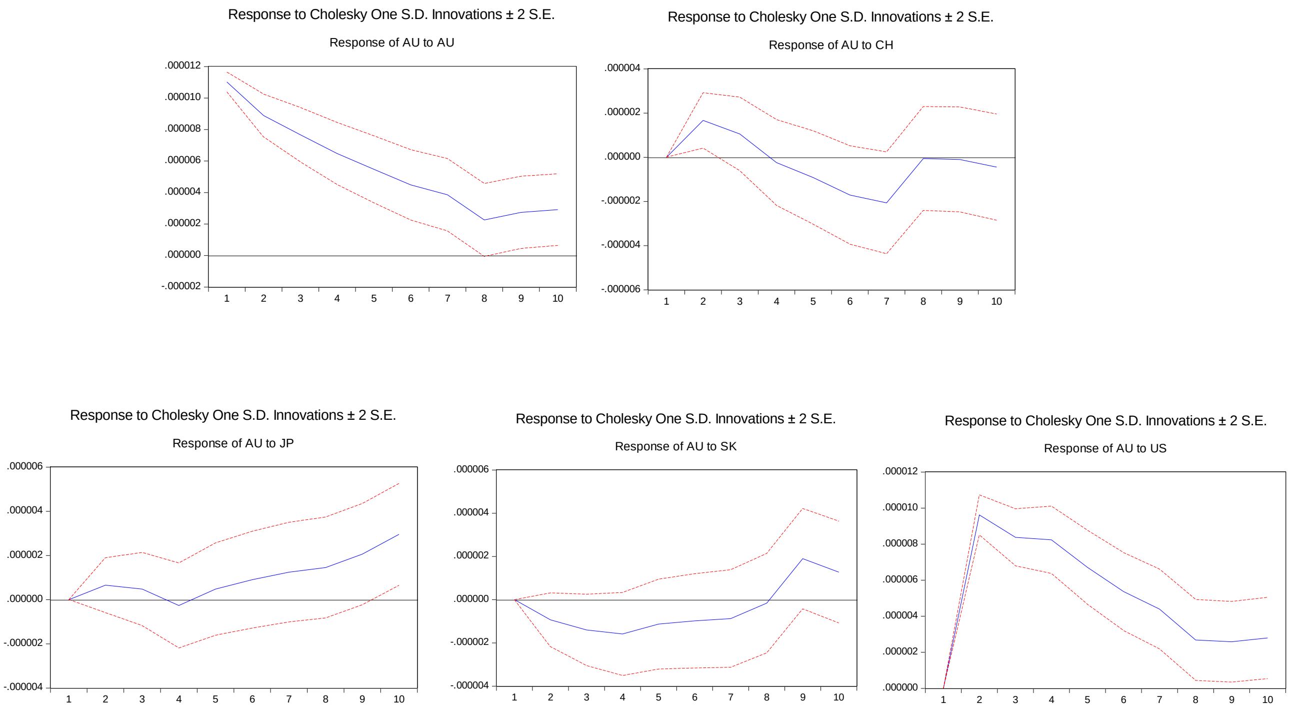
The Australian market also Granger causes the volatility in the Japanese, South Korean, Chinese and US markets. Apart from the Chinese and Australian markets, there is a causal relationship running from the Japanese market to the rest. Further to the analysis of the results in the table, with the exception of the Chinese market, the volatility in the South Korean market Granger causes the volatility in the Australian, Japanese and US markets. It can be seen from all these causal relations that there is a feedback from the markets and contingent effects across the markets. In comparison with the Japanese market, there is strong statistically significant causality proceeding from the US market to the remaining markets. This implies that the yen-US dollar volatility in all the other markets is caused mainly by the volatility in the US market than by volatility in the Japanese market.

From the results, it is difficult to disentangle the channels of causation and where exactly the volatility started, as most of the markets show bi-directions. There is a unidirectional causal relationship from the Chinese market to the Japanese and South Korean markets. This, however, does not demonstrate that the Chinese market is a dominant source of causation as the volatility in that market itself is strongly caused by the volatility in the US market. It can be noted from the results in Tables 5 and 6 that although the volatility in the US market is caused by the other markets, it depends significantly on the Japanese as well as its own lagged volatility.

5.3. Impulse responses

In this section, impulse responses of the volatility in the markets for a given shock to a specific market are examined using a VAR based T-Y procedure estimation. Figure 3 plots the responses of the Australian market to the shocks given to the Chinese, Japanese, South Korean and US markets. While the vertical axis stands for the volatility in response to a given shock on the specific market, the horizontal axis denotes the days that elapsed after the introduction of the shock. The dotted lines are the confidence intervals which determine the significance of the responses. The results show positive and statistically significant responses of the volatility in the Australian market to the volatility in the Chinese, US and its own market. Its significant response to the Chinese market is short-lived. On the other hand, the significant response of the market to its own volatility and the US volatility is long-lasting. The magnitude of the response to its own volatility, however, is greater than its response to the US volatility.

<u>Figure 3. Impulse responses of the Australian market</u>



As can be seen in Figure 4, in contrast to the responses of the Australian market to the shocks of the Chinese market, the response of the Chinese market to the shock of the Austrlain market lasts relatively longer. This suggests that the Australian market has a greater role in the determination of the volatility of yen-US dollar in the

Chinese market than does the Chinese market in the yen-US dollar volatility in the Australian market. Although there is a significantly greater response to its own shock compared to the Australian market's shock for the first day, on average, the magnitude of the response to the shocks of the volatility in the US market is greater. The figure also shows that the response of the Chinese market to the shocks in the US and Australian markets lasts longer relative to its own shock. This indicates that the US and Australian markets are most influential for the yen-US dollar volatility in the Chinese market. The figure indicates that there is insignificant response of the volatlity in the Chinese market to the Japanese and South Korean markets.

<u>Figure 4. Impulse responses of the Chinese market</u>

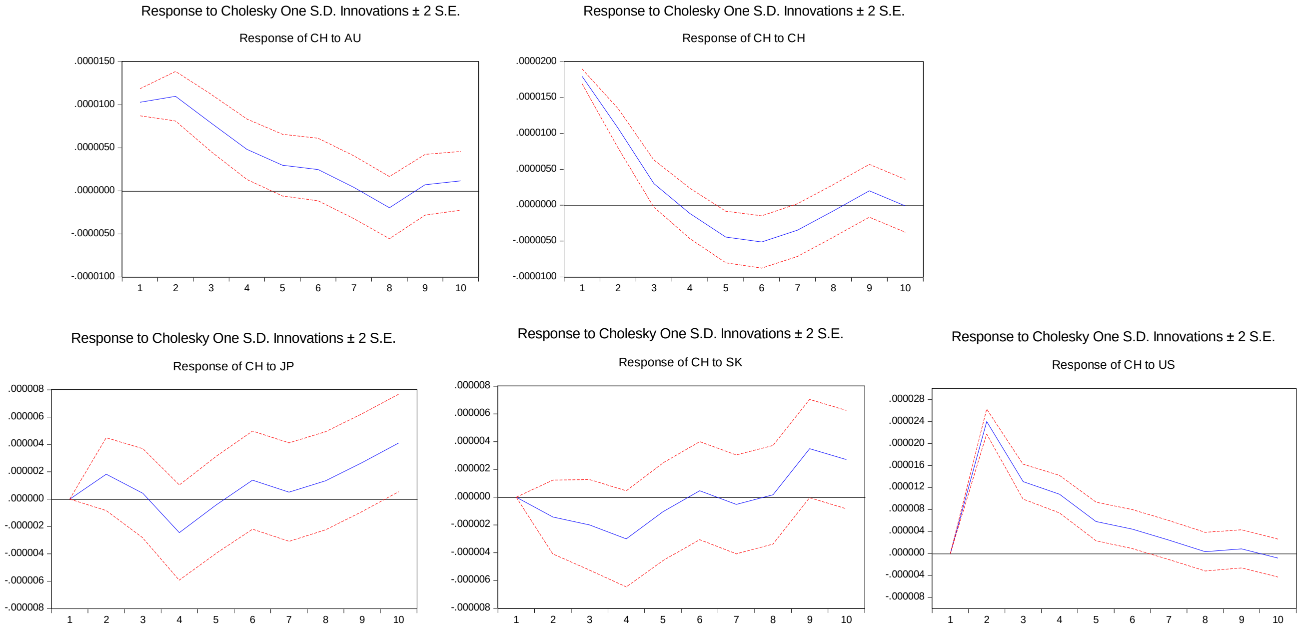
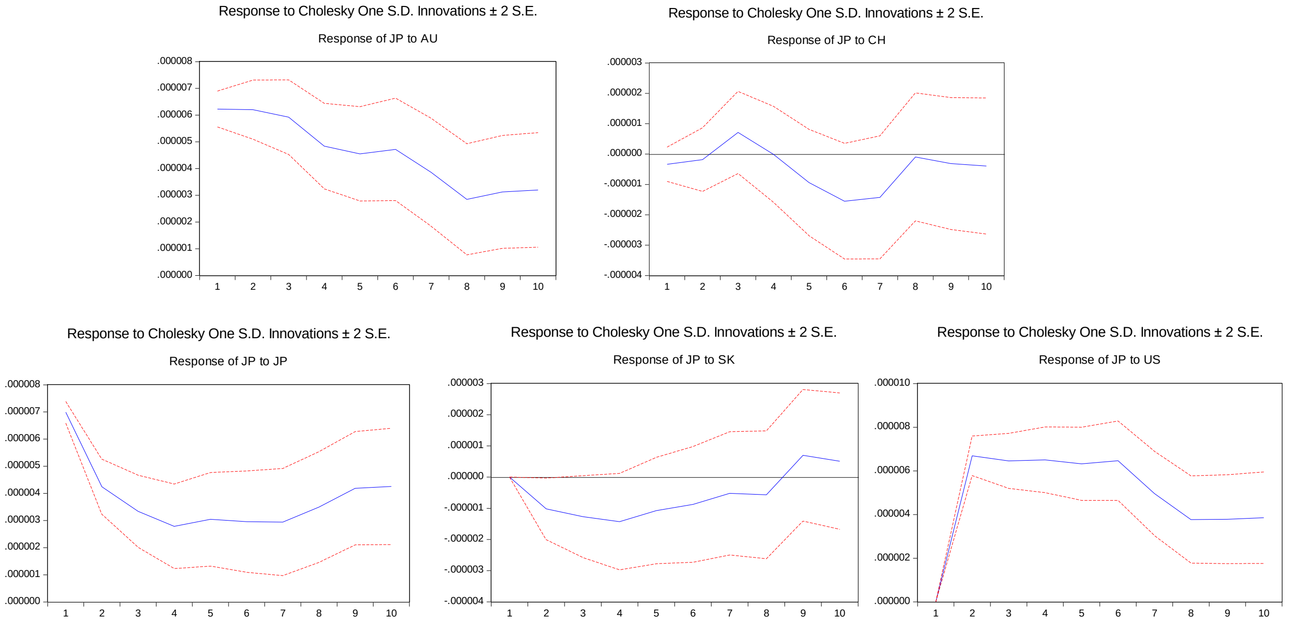


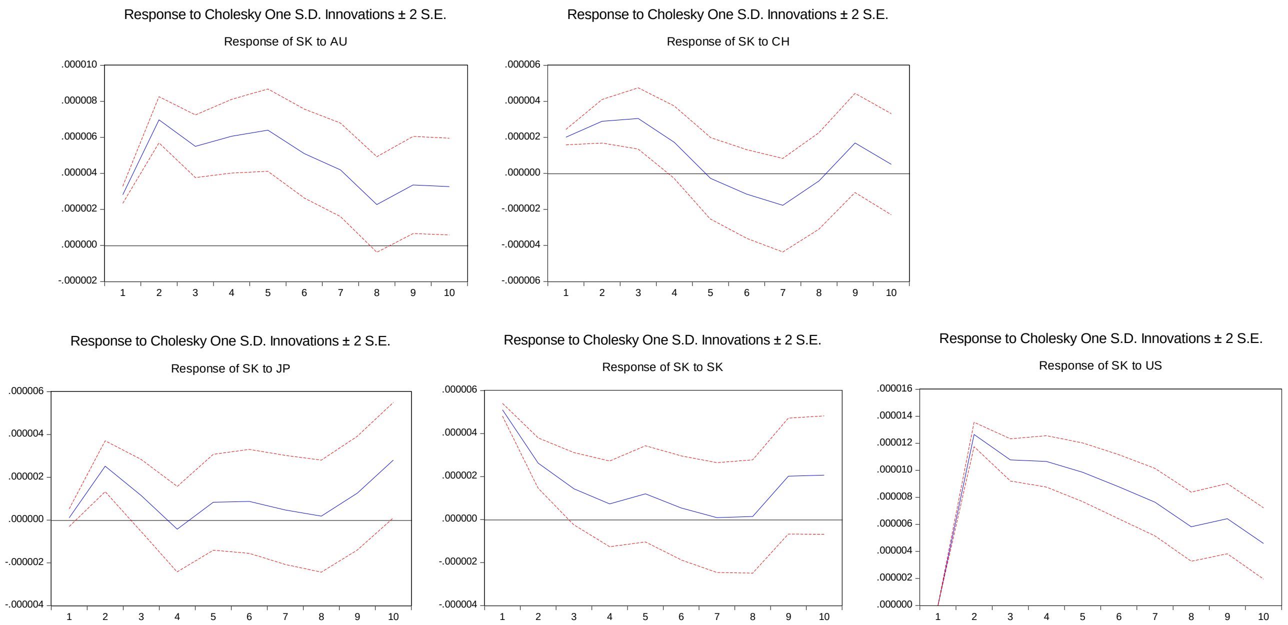
Figure 5 plots the responses of the Japanese market to different shocks of the markets. The volatility of the yen-US dollar in the Japanese market does not respond significantly to the shocks given by the volatility in the Chinese and South Korean Markets. However, there are statistically significant responses of the volatility in the Japanese market to the shocks in the Australian, Japanese and US markets. It can be noted here that in contrast to the previous responses shown in the figures above, the statistically significant responses of the volatility in the Japanese market do not die out. In other words, there is a long-lasting reaction of the yen-US dollar volatility in the Japanese market to the shocks of its own, the Australian and US markets. Furthermore, in the first few days, the extent of the response is higher to its own shock relative to the shocks in the other markets. As the days go by, the large significant response of the market to its own shock is overtaken by its response to the US shock. However, after about 8 days or one week and half, the large and significant response of the market is replaced again by its responses to its own shock.

Figure 5. Impulse Responses of the Japanese market



The impulse responses of the South Korean market to the shocks given to the Australian, Chinese, Japanese and the US markets are statistically significant, as shown in Figure 6. The significant response of the market to the shocks in the Japanese market is short-lived which lasts only for a day. Likewise, its responses to its own shocks and the shock given to the Chinese market die out quickly. On the other hand, its reactions to the shocks in the Australian and the US markets remain for relatively longer periods. In both cases, its responses mount for the first two days and then decline gradually. As in the case of the responses of the Chinese market, the extent of the response to the shocks in the US market is higher than to its own shocks. It is clear from the figure that its responses to its own shock became insignificant after three days, suggesting that the market plays smaller role in the yen-US dollar volatility within the market.

Figure 6. Impulse Responses of the South Korean market



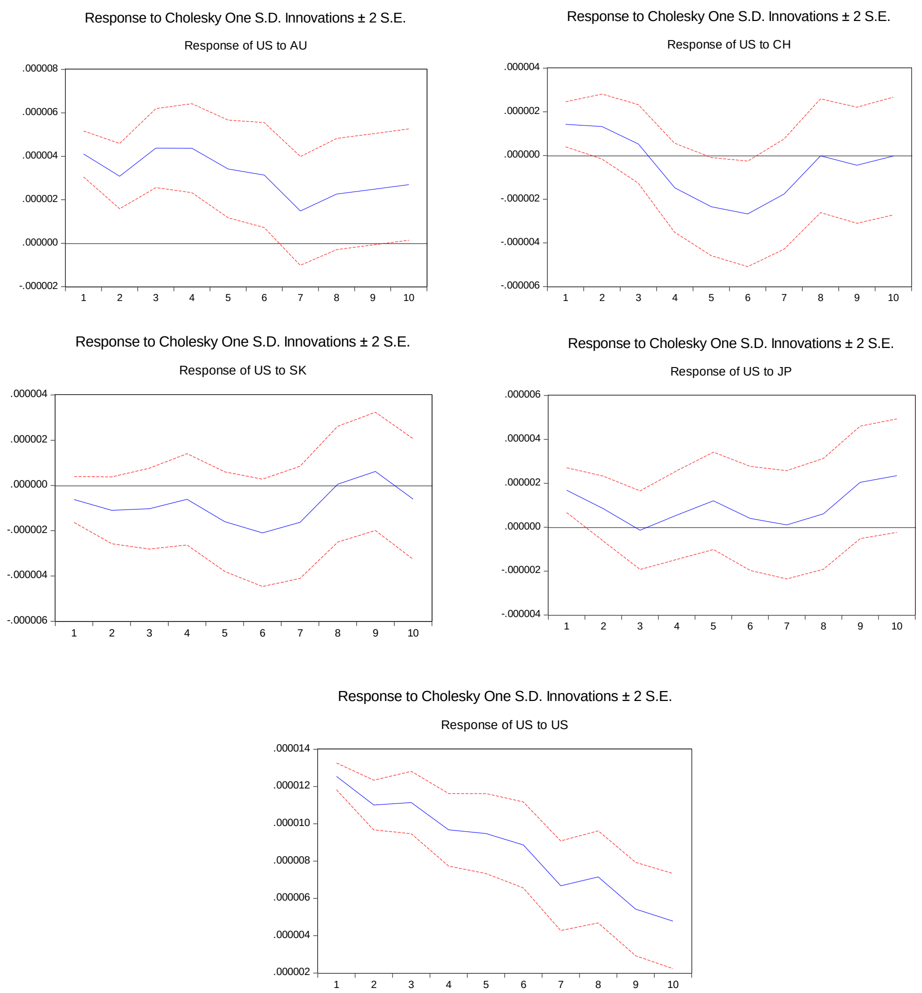
The impulse responses of the US market are shown in Figure 7. Apart from its responses to the shocks of the South Korean market, the market reacts significantly to all the shocks of the remaining markets. The responses to its own shock and those in the Australian market last longer compared to its responses to the shocks in the Chinese and Japanese markets. The magnitude of the responses is higher to its own shock than to those of the Australian, Chinese and Japanese markets.

In summary, it can be noted that the existence of higher responses to their own shocks in most of the results discussed so far suggests the dominance of "heat waves" relative to "meteor showers". This implies that own volatility has greater role in own predictability than trading partners' volatility. It can also be noted that, with the exception of its own market, the shock given to the South Korean market produces insignificant responses of all the markets. In contrast to this, the shocks in the Australian and US markets yield significant responses from all the markets including their own. This indicates that the South Korean market has minimal role in the yen-US dollar volatility while the Australian and the US markets have greater roles.

6. Conclusion

Exchange rate movements are generally dictated by the decisions of the participants in the foreign exchange markets which are sensitive to the news of socio-economic and political changes. By and large, the movements tend to get bigger during financial crises than they do as a result of any other disturbances. The rises in exchange rate volatility across the globe as a result of the US financial market crisis are typical cases of these patterns. This paper addresses the most crucial points that need to be highlighted in the studies of exchange rate volatility and thereby contributes in four different areas.

<u>Figure 7. Impulse responses of the US market</u>



First, it examines to what extent a market's own past volatility plays its role in the determination of exchange rate volatility of the Australian, Chinese, Japanese, South Korean and US markets once the crisis struck. Second, it addresses whether there was a feedback from the markets enhancing the volatility spillover and to what extent trade links contribute to it. Third, in contrast with the existing studies on “meteor showers” versus “heat waves”, this paper sheds light on spillover directions by employing the Toda and Yamamoto Granger non-causality test. Fourth, it examines whether or not unlagged (rapidly transmitted without delay) information wields significant influences in determining market reaction relative to lagged information.

The results indicate that the volatility of yen-US dollar quoted in all the markets is time varying and asymmetric, implying that depreciation of the US dollar has a greater impact on volatility than appreciation. Volatility persists across the markets suggesting that it does not die out and adjust towards equilibrium (stability) easily. The persistence also suggests the existence of feedback to the volatility spillover across the markets which are linked by trade. The estimation results and the impulse responses show that own past volatility, “heat waves”, has greater impact than trading partner’s past volatility, “meteor showers” in the Australian, Japanese and US markets. This implies that the markets can mainly be predictable by their own past volatility.

The results of the Toda and Yamamoto Granger non-causality test suggest that there is a unidirectional causal relationship from the Chinese to the Japanese and South Korean Markets. However, this may not indicate that the Chinese market is a dominant source of the volatility as the volatility in the market itself is largely caused by the volatility in the US. The bi-directional causal relationship in most of the markets shows the feedback and role of trade in the markets. On the estimation of lagged versus unlagged information results, there is evidence that unlagged information has a positive impact on the market reaction and therefore on the volatility of the markets. The degree of its influence, however, is minimal compared to the impact of lagged information. This has several implications, one of which is that market players are cautious in their decisions and might take time in adjusting to the news.

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