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Implied volatility transmissions between Thai and selected advanced stock markets

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Abstract

This paper investigates the impacts of changes in the U. S. implied volatility on the changes in implied volatilities of the Euro and Thai stock markets. For that purpose, volatilities implicit in stock index option prices from the U. S., Euro and Thai stock markets are analyzed using the standard Granger causality test, impulse response analysis, and variance decompositions. The results found in this study suggest that the U. S. stock market is the leading source of volatility transmissions since the changes in implied volatility in the U. S. stock market are transmitted to the Euro and Thai stock markets.

Keywords: Stock index option prices, implied volatility, causality, impulse response functions, variance decompositions

JEL classification: G15, C22

1. Introduction

Empirically, return and volatility transmissions across stock markets based on market returns and volatilities are investigated to find the degree of stock market integration using various econometric techniques. The econometric techniques include cointegration test, causality test, generalized autoregressive conditional heteroskedastic (GARCH) model estimation, correlation and regression analyses. For example, Liu and Pan (1997) use a GARCH model to examine the mean return and volatility spillover effects from the U. S. and Japanese stock markets to four Asian stock markets (those of Hong Kong, Singapore, Taiwan and Thailand). Their main finding indicates that the U. S. stock market is more influential in transmitting return and volatility to the four Asian markets. Raj and Dhal (2008) find high correlations of stock price indices that strengthen the integration of India's stock market with global and regional markets. Further, the absolute size of coefficients in the long-run relationship suggests that the Indian stock market is dependent on global markets, i.e., the U. S. and U. K. stock markets. Besides, Chiang et al. (2007) uses dynamic correlation analysis and find evidence for the contagion effects between Asian markets. However, there is an argument that implied volatility as a measure of volatility or uncertainty in a stock market can be more useful. According to Fleming et al. (1995) and Whaley (2000), implied volatility is affected by both positive and negative return shocks. This implied volatility index falls for positive return shocks and rises for negative return shocks. Bollerslev and Zhou (2006) find that the asymmetric response of current volatility to lagged negative and positive returns is stronger for implied volatility than realized volatility.¹

¹ Blair et al. (2001) also find that applying implied volatility is useful when predicting future volatilities. The evidence of a negative relationship between stock index return and its corresponding implied volatility can be found in Giot (2005) and Badshah (2013).

Nikkinen and Sahlström (2004) use implied volatility indices test for market integration. They find a high degree of integration among the U. S., U. K. and German stock markets. The U. S. stock market transmits volatility to the other markets while German market transmits volatility to the other European stock markets. Recent empirical studies using different methods show that financial shocks play an important role in spillover effects among stock markets. Peng and Ng (2012) find evidence of financial contagion in five popular indices of advance stock markets. The degree of dependency is influenced by financial shocks. Siriopoulos and Fassas (2013) employ dynamic conditional correlation to examine the spillover effects across international financial markets using implied volatility indices. They find that capital market integration increases in the periods of financial turbulence. Kenourgios (2014) employs the dataset from a sample of international implied volatility indices on daily changes basis and finds evidence indicating the existence of contagion in cross market volatilities. The most contagious phase is the early phase of global financial crisis.

The present study contributes to the existing literature by providing evidence of implied volatility transmissions between an emerging stock market (the Stock Exchange of Thailand or SET) and two international stock markets (those of the U.S. and Euro markets). The methods used in the analysis are similar to those of Nikkinen and Sahlström (2004) and Äijö (2008). Since the dataset used is limited by the emergence of SET50 index option prices, the study cannot detect the impact of the U. S. subprime crisis that can affect the results of the analyses. The main findings of the present study are that: (1) there is a unidirectional causality running from the U. S. implied volatility changes to those of the Euro and Thai stock markets, and (2) the impulse response analysis and variance decompositions seem to support the results from causality analysis. The next section presents the methodology used in this study. Section 3 presents empirical results and the last section gives concluding remarks.

2. Methodology

2.1 Data

This study employs daily data during November 2010 to December 2013. The prices of SET50 index options are used as an emerging market index, i.e., major sub-index of the Stock Exchange of Thailand. The implied volatility indexes of the large two international stock markets are the Euro STOXX50 index and the U.S. S&P500 implied volatility index. The number of observations is 634.² The dataset is obtained from SETSMART (SET Market Analysis and Reporting Tools), and Thomson Financial DataStream.

Practically, the implied volatility index indicates the consensus view about the expected future realized stock index volatility (see e.g. Whaley, 2000). Implied volatility indexes are typically available in advanced stock markets, but the implied volatility index is not available in Thailand. Therefore, this index is calculated using the Black and Sholes (1973) option pricing formula, which is the most widely used because of its consistency with the assumption that investors in an option market behave as if they employ this formula to evaluate the option prices (see Christensen and Prabhala, 1998, among others). The valuation model of option is specified as:

$$C(S, t) = SN(d_1) - Ke^{-r(t-T)}N(d_2) \quad (1)$$

²The number of observations is limited by the availability of the price of the SET50 index options that will be used to estimate the implied volatility index. The SET50 index is calculated from stock prices of the top 50 listed companies with large market capitalization in the Stock Exchange of Thailand.

where C is the option price, S is the current stock price, K is the option striking price or exercise price, r is the risk-free rate, T is the expiration date of the option. The cumulative normal density functions (N s) of two variables, d_1 and d_2 , are normally distributed with a mean of zero and a standard deviation of one. These variables are specified as:

$$d_1 = [\ln(\frac{S}{K}) + (r + \frac{1}{2}\sigma_s^2)(T - t)] / \sigma_s \sqrt{(T - t)} \quad (2)$$

and

$$d_2 = d_1 - \sigma_s \sqrt{(T - t)} \quad (3)$$

where σ_s is the standard deviation of stock price. The expression $SN(d_1)e^{-r(T-t)}$ is the expected value that is equal to S_T if $S_T > K$ and zero otherwise. The function $N(d_2)$ is the probability that the option will be exercised so that $KN(d_2)$ is the striking price multiplied by the probability that the striking price will be paid.

One of various parameters in the Black and Sholes pricing formula that cannot be directly observed is the volatility of the underlying stock price. However, it is possible to gauge such a volatility value that causes the option value to be consistent with the market price of an option. In calculating the implied volatility in a stock market, one can plug in the values of all parameters in the option pricing formula, including the option price from an option market. Then the iterative procedure can be used to calculate the implied volatility such that the option price obtained from the formula is equal to the actual option price observed in the option market (Watsham and Parramore, 1997). Since the established volatility is the implied volatility for each individual option at each exercise price, the implied volatility index should be computed as an average of all individual implied volatilities from the at-the-money options or near-the-money options. Such calculation is consistent with the fact that the price of at-the-money option is far more sensitive to volatility than the price of deep-out-of-the-money option. According to Hull (1997), this calculated volatility is more informative to the true implied volatility.

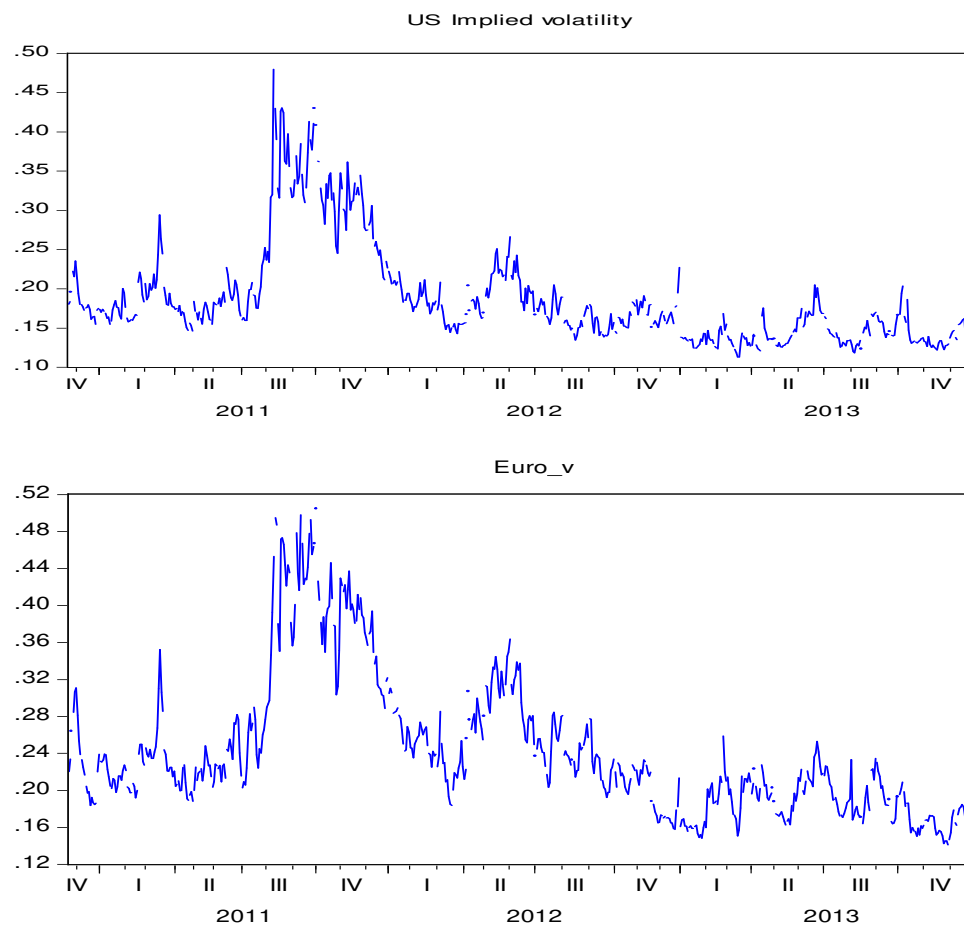
Table 1 presents the descriptive statistics of implied volatilities in the four stock markets. Panel A of Table 1 presents the sample properties of implied volatility series in their level. The descriptive statistics show that implied volatility series are generally similar because all series have positive means with high kurtosis. However, first differences of all series exhibit small values of negative means, but with higher standard deviation as shown in Panel B of Table 1.

Table 1 Descriptive statistics of implied volatilities, November 2010-December 2013

	v^{US}	v^{Euro}	v^{TH}
Panel A: Level			
Mean	0.187	0.243	0.218
Median	0.170	0.223	0.210
Maximum	0.480	0.504	0.486
Minimum	0.113	0.141	0.082
Standard deviation	0.063	0.075	0.068
Skewness	1.862	1.362	0.882
Kurtosis	6.333	4.441	3.967
Panel B: Difference			
Mean	-8.8E-05	-8.8E-05	-2.7E-05
Median	-0.0007	-0.0008	-0.0004
Maximum	0.1600	0.1213	0.2280
Minimum	-0.0889	-0.1066	-0.1686
Standard deviation	0.0179	0.0191	0.0295
Skewness	1.6249	0.3512	0.9373
Kurtosis	17.8339	9.0204	19.5125

Note: v^{US} stands for implied volatility of U. S. S&P500 index options, v^{Euro} stands for implied volatility from Euro STOXX50 index options, and v^{TH} stands for implied volatility of SET50 index options.

The implied volatilities of the three stock markets during the sample period are illustrated in Figure 1.



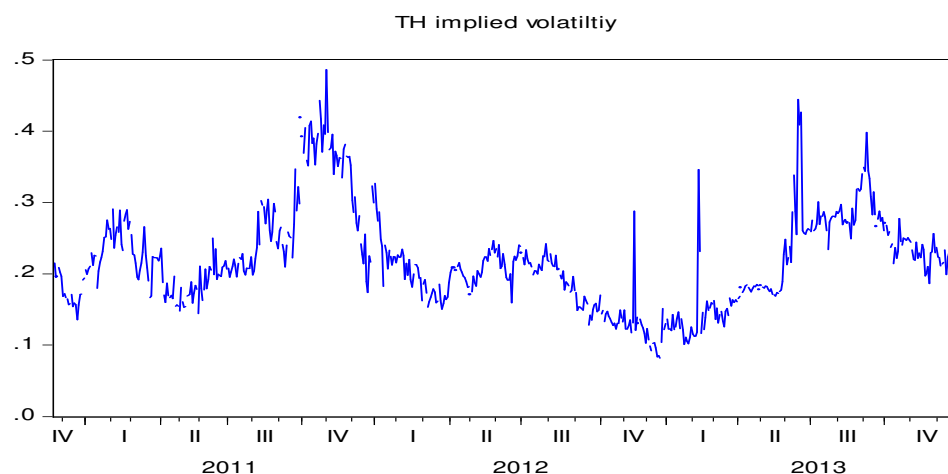


Figure 1. Implied Volatilities of the U. S., Euro and Thai stock markets

Figure 1 shows the plots of uneven implied volatilities of the three markets. However, the patterns of implied volatilities of the U. S. and Euro stock markets are similar. The implied volatility of the Thai stock market seems to be different from the other two markets.

To examine the stationarity property of implied volatilities, the Augmented Dickey and Fuller (ADF) and Phillips and Perron (PP) tests with a constant are applied. Table 2 presents the results of unit root test without a linear trend.

The results of unit root tests in Panel A of Table 2 give mixed results for the four implied volatility series. However, the results in Panel B of Table 2 indicate that changes in all implied volatilities are stationary. Therefore, differences of implied volatility series are used in the analysis.

Table 2 Results of unit root tests

	ADF statistic	PP statistic
Panel A: Level of implied volatility		
v^{US}	-1.962 [12] (0.304)	-3.274 [2] (0.017)**
v^{Euro}	-2.170 [4] (0.218)	-2.546 [4] (0.105)
v^{TH}	-2.840 [3] (0.000)***	-4.813 [10] (0.000)***
Panel B: Difference of implied volatility		
Δv^{US}	-8.409 [11] (0.304)***	-29.897 [14] (0.000)***
Δv^{Euro}	-16.472 [3] (0.000)***	-26.881 [25] (0.000)***
Δv^{TH}	-16.752 [3] (0.000)***	-43.294 [15] (0.000)***

Note: The number in brackets is the optimal lag length determined by AIC for the ADF test and the optimal bandwidth determined by the Bartlett kernel for the PP test. The number in parenthesis is the p-value. ***, and ** denote 1 and 5 percent significance level, respectively.

2.2 Analytical Framework

This study employs the vector autoregressive (VAR) model proposed by Sim (1980), which is suitable to estimate the relationships among variables. In addition, Granger (1969) causality test is employed to determine the direction of causality between stationary variables in the model. Following the works of Nikkinen and Sahlström (2004) and Äijö (2008), the VAR(p) model can be expressed as:

$$\Delta y_t = \mu + \sum_{i=1}^p A_i \Delta y_{t-i} + e_t \quad (4)$$

where Δy is a 3x1 vector of changes in implied volatilities (Δv), μ is a 3x1 vector of intercepts, $\{A_i, i=1,2,\dots\}$ is a 3x3 matrix of autoregressive coefficients, e is a 3x1 vector of random errors with zero means and positive definitive co-variances. The optimal lag p can be determined by Akaike information criterion (AIC), Schwarz information criterion (SIC) or final prediction error (FPE).

In examining the spillovers of implied volatilities from one stock market to another stock market, one can employ this VAR system to analyze the time structure of transmissions under the assumption that there exist causal relationships between implied volatilities. Equation (4) is used to examine the dynamic impact of random innovations on a system of variables. The specified VAR model treats each endogenous variable in the system as a function of lagged endogenous variables in dynamic simultaneous equations.

3. Empirical Results

The standard Granger causality test and VAR(p) estimation are performed on first differences of implied volatilities. In so doing, the appropriate lag length needs to be determined. Table 3 presents the lag order selection for VAR(p) model. While Akaike information criterion (AIC) and final prediction error (FPE) give the optimal lag of four, Schwartz information criterion (SIC) gives the optimal lag of two. Since the Breusch-Godfrey LM test shows that the VAR system with the lag of four indicates no serial correlation, the lag of four is applied in the VAR analysis and Granger causality test.

Table 3 Criteria for lag order selection of VAR(p) model

Lag	AIC	SIC	FPE
0	-15.106	-15.085	-5.52E-11
1	-15.427	-15.342	-4.01E-11
2	-15.516	-15.367*	-3.67E-11
3	-15.573	-15.360	-3.46E-11
4	-15.577*	-15.301	-3.45E-11*
5	-15.564	-15.223	-3.49E-11
6	-15.547	-15.142	-3.55E-11
7	-15.533	-15.064	-3.60E-11
8	-15.534	-15.001	-3.60E-11

Note: * indicates the optimal lag length for each criterion.

The results of Granger causality test is reported in Table 4. The test shows directions of causality between each pair of changes in implied volatilities.

Table 4 Results of Granger causality test

Null hypothesis	F-statistic	p-value
v^{US} does not Granger cause v^{Euro}	12.256	0.000***
v^{Euro} does not Granger cause v^{US}	0.531	0.713
v^{US} does not Granger cause v^{TH}	2.273	0.060*
v^{TH} does not Granger cause v^{US}	1.314	0.263
v^{Euro} does not Granger cause v^{TH}	1.023	0.395
v^{TH} does not Granger cause v^{Euro}	1.186	0.316

Note: The test is performed on changes in implied volatility. ***, **, and * indicate significance at the 1, 5 and 10 percent respectively.

The results in Table 4 show that the implied volatility of the U. S. stock market causes implied volatilities of Euro and Thai stock markets. However, implied volatilities of Thai and Euro stock markets do not cause implied volatilities of the U. S. stock market. Therefore, it can be concluded that implied volatility transmits from the US stock market to the Euro and Thai stock markets.

Table 5 Summary statistics of the results from the VAR(4) model estimate

	Δv^{US}	Δv^{Euro}	Δv^{TH}
Adjusted R^2	0.070	0.115	0.198
F-statistic	4.943	7.834	11.057
	(p-value=0.000)	(p-value=0.000)	(p-value=0.000)
Q(8)	5.474	9.786	8.393
	(p-value=0.706)	(p-value=0.280)	(p-value=0.396)

Note: Q(k) is the Ljung-Box test for serial correlation of each equation in the VAR system.

To analyze the predictability and implied volatility transmissions of the three stock markets in more detail, the impulse response functions are obtained from the VAR(4) model. The summary statistics of the results from the VAR(4) model estimate are presented in Table 5.

The adjusted R^2 ranges from 0.070 to 0.198. In addition, the F-statistics indicate that the VAR(4) model is significant at the 1 percent with the p-value of less than 0.01. The Ljung-Box statistic for eight lags show no serial correlation in the residuals, suggesting the VAR(4) model is adequate. The contemporaneous residual correlations from the VAR(4) model estimate between the three stock markets are reported in Table 6.

Table 6 Residual correlations from the VAR(4) model estimate

	US	Euro	TH
US	1.000		
Euro	0.725	1.000	
TH	0.098	0.142	1.000

Note: US denotes residuals from Δv^{US} , EURO denotes residuals from Δv^{EURO} , and TH denotes residuals from Δv^{TH} .

The results in Table 6 show that the highest correlation coefficient of 0.725 is between implied volatilities of the U. S. and Euro stock markets. The correlation coefficient between implied volatilities of the Thai and Euro markets is 0.142 while the correlation coefficient between implied volatilities of the Thai and U. S. market is 0.098. The latter two coefficients are quite low. The results are consistent with the results of Granger causality test, which suggest that the U. S. stock market is influential in transmitting implied volatilities to the other two stock markets.

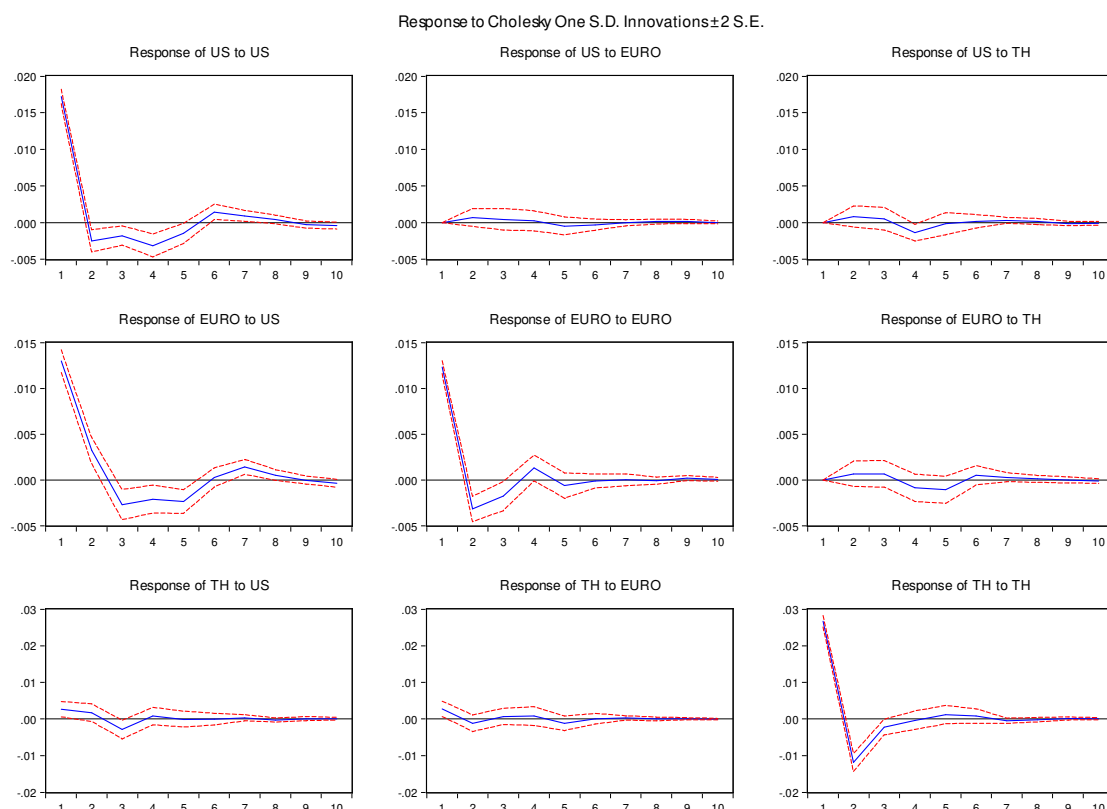


Figure 2 Impulse responses of implied volatility changes

The results of impulse response analysis are shown in Figure 2. The figure shows the impulse response functions and the Monte Carlo simulated at 95 percent intervals.

The responses of the implied volatility of the Euro stock market to a shock in the implied volatility of the U. S. stock market show that the Euro volatility increases on the next day following the contemporaneous effect of that shock. This impact starts to decay and the whole impact is incorporated with in three days. Thereafter, there is a negative impact that lasts for another two days. The response of the implied volatility of the Thai stock market to a shock in implied volatility of the U. S. stock market is similar but with lower degree of response and fewer days. Finally, the responses of the U. S. implied volatility to shocks in the implied volatilities of the Euro and Thai markets are incorporated within one day. These findings show that the U. S. implied volatility leads the other two implied volatilities.

Variance decompositions that are used to ascertain how important the innovations of other variables are in explaining the fraction of each variable at different step ahead forecast variances are presented in Figure 3.

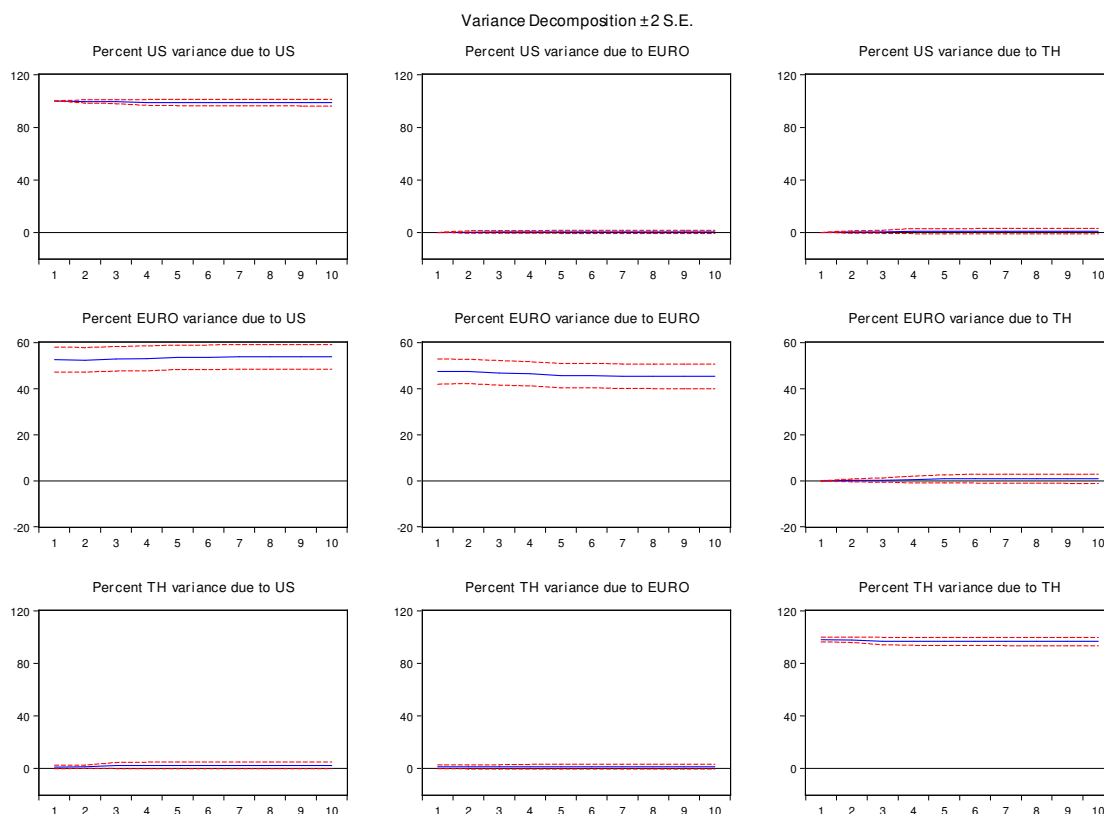


Figure 3 Variance decompositions of changes in implied volatilities

In Figure 3, the dashed lines represent the Monte Carlo simulated at 95 percent confidence intervals. The results provide evidence for the independency of the implied volatility of the U. S. stock market because its forecast variance is only caused by its own innovations. Furthermore, the implied volatility of the U. S. market has a significant impact on the Euro implied volatility, but has no impact on the Thai implied volatility. Finally, the Euro implied volatility has no impact on the Thai implied volatility.

The results clearly show that the U. S. stock market is influential in transmitting volatility as a measure of uncertainty to the Euro and Thai stock markets. However, the Thai stock market is not dependent on the Euro stock market. It should be noted that the period of investigation is the period after subprime crisis. Therefore, the linkages between implied volatility indexes are not strengthened by financial shocks as evidenced by the results of Peng and Ng (2012) and Siriopoulos and Fassas (2013). The findings in the present paper give recent knowledge for portfolio managers since they need to know the degree of dependency across stock markets so that they can diversify more efficiently.

4. Concluding Remarks

This study uses the standard Granger causality test and the VAR(4) models to examine implied volatility indices of the U. S., Euro and Thai stock markets. The empirical results from analyzing the daily data from November 2010 to December 2013 indicate the following: (1) the VAR(4) model employed fits the data generally well; (2) there is implied volatility transmissions from the U. S. stock market to the Euro and Thai stock markets, but not the other way around; (3) the Euro stock market does not influence the Thai stock market in terms of implied volatility spillover. The results have important implication for portfolio managers operating in the international stock markets in that they can improve their portfolio

performance by taking into account the dependencies between implied volatility indices across emerging and advanced stock markets.

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