RELATIONSHIP OF THE CHANGE IN IMPLIED VOLATILITY WITH THE UNDERLYING EQUITY INDEX RETURN IN THAILAND

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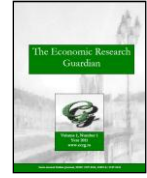Administration, Bangkok, Thailand
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Abstract

In this study, we examine the relationship between the change in implied volatility index and the underlying stock index return in the Thai stock market. The data used are daily data during November 2010 to December 2013. The regression analysis is performed on stationary series. The empirical results reveal that there is evidence of significantly negative and asymmetric relationship between the underlying stock index return and the change in implied volatility. In addition, the size effect of the underlying stock index return and the one-period lagged implied volatility change also affect the change in implied volatility. The finding in this study gives implication for risk management.

Keywords: Equity index return, Option prices, Implied volatility, Asymmetric effect

**JEL classification:** G15, C22, C32

1. Introduction

The leverage effect posits that stock return shocks lead to asymmetric changes of expected volatilities in stock markets (see details in Black, 1976, and Christie, 1982). For the implied volatility literature, the evidence on the asymmetric impacts of the underlying index returns on implied volatility indices has been recently well-documented.[1] The implied volatility index can measure investors' sentiment or fear. Investors' fear is defined in the sense that a decline in the equity index or negative index return and if negative return is associated with an asymmetrically larger rise in the implied volatility index, investors will take this phenomenon into account when they make decision.

The asymmetric relationship between index return and the change in implied volatility index is well documented (see for examples, Flemming et al., 1995, Whaley, 2000, and Giot, 2005). Specifically, Giot (2005) finds that the S&P100 index exhibits the statistically negative relationship with its implied volatility. The relationship exhibits asymmetry and thus indicates that negative stock of return yields bigger change in the corresponding implied volatility than positive shock of return does. Low (2004) examines the relation between return and implied volatility of the S&P100 index options and finds that this relationship is asymmetric and nonlinear, and best described by a downward-sloping reclined S-curve. Bollerslev and Zhou (2006) find that the leverage effect is always stronger for implied volatility than realized volatility in the US stock market.[2] Dennis et al. (2006) examine the dynamic relation between daily stock return and daily innovations in option-derived implied volatility. They find that the asymmetric relation between return and implied volatility primarily stems from systematic market-wide risk factors rather than aggregate firm-level effects. In other words, the return-implied volatility relation should be a market phenomenon. Hibbert et al. (2008) examine the short-term dynamic relation between the S&P500 and Nasdaq100 index returns and changes in implied volatility in both daily and intraday level. Their findings reveal that neither the leverage nor volatility feedback effects adequately explained their results. Instead, a strong daily and intraday negative return-implied volatility relation stems from the representativeness from behavior of traders and the extrapolation bias concepts. Fernandes et al. (2014) find the results that confirm the evidence suggesting that there is a negative relationship between implied volatility index and the S&P500 index return. Badshah (2013) uses quintile regression to examine the short-term relation between stock index returns and changes in implied volatility indexes in the US and some European stock markets. One of the main findings from this research reveals that there exists strongly negative and asymmetric relation between each implied volatility index and its corresponding stock market index. The asymmetry increases monotonically from the median quantile to the uppermost quantile.

For other stock markets, Tang (2007) finds a negative correlation between the index return and the implied volatility in the Korean stock market. Frijns et al. (2010) finds that the relationship between implied volatility and the underlying index return is significantly negative and asymmetric in the Australian stock market. Siriopoulos and Fassas (2012) find that there is a significant negative and asymmetric relationship between the change in implied volatility index and the underlying equity

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[1] Implied volatility index is also known as the investors fear guage index (Whaley, 2000).
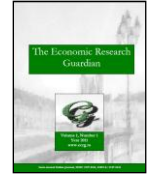[2] Realized volatility is usually measured by the variance of return.
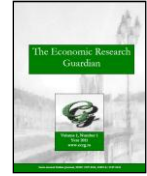
index return in the Greek stock market, which is contradictory to the previous finding of Skiadopoulos (2004) that the relationship does not exist. However, Ederington and Guan (2010) find negative and asymmetric relationship without the size effect. Lee et al. (2012) use the autoregressive conditional jump intensity model to investigate the relationship between the changes in implied volatility and the underlying index return for the Taiwan stock market. They find that the changes in implied volatility are affected by contemporaneous return, lagged return, lagged changes in implied volatility and other variables. Shaikh and Padhi (2014) investigate the contemporaneous inter-temporal relationship between the change in implied volatility index and stock return in India. They find the negative and asymmetric effect in the Indian stock market. Lee and Ryu (2013) reexamine the relationship between return and implied volatility to make a comparison between the US and Korean stock markets using a new vector auto-regression framework. They find the existence of asymmetric volatility phenomenon in both markets even though the impulse response dynamics in the Korean stock market are quite different from those of the US stock market.

Even though there is a growing literature on the relationship between the implied volatility indices and their underlying stock index returns in advanced stock markets, few research works have been conducted regarding emerging stock markets.[3] Furthermore, the majority of past studies use weekly and monthly data on realized volatility to analyze this relationship (Hibbert, et al., 2008, among others). The present paper contributes to the above-mentioned literature by constructing the option-derived implied volatility index for Thailand using available daily data of option prices. It also directly investigates the relationship between daily changes in the Thai implied volatility index (Thai VIX) and the returns of the SET50 index. We use the Thai stock market as a case study of emerging Asian stock markets because very few studies on implied volatility and its underlying index return are conducted for this region, e.g., the work by Tang (2007). The results from our regression analysis suggest that there exists significantly negative and asymmetric relationship of the change in implied volatility index with the underlying stock index return in the Thai stock market. The existence of this relationship is consistent with the phenomenon found in many advanced stock markets. Our paper is organized as follows. The next section describes our analytical framework, which comprises the data and empirical models used in the regression analysis. Section 3 presents empirical results and the last section concludes.

2. Methodology

We use our computed daily Thai implied volatility index (Thai VIX) instead of realized volatility index because the option-derived volatility index does not cause problems in estimations, especially sampling and specification errors. Therefore, our analysis will focus on the relation between the change in implied volatility and its underlying index return.

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[3] Previous studies on the risk-return relationship using different volatility models to generate conditional variance as a measure of risk are common in the literature. However, fewer studies employ implied volatility as a measure of risk even in advanced stock markets.

2.1. Data

The data in this study are high-frequency data, which are obtained from SET Market Analysis and Reporting Tools (SETSMART) and Thompson Financial DadaStream. The dataset consists of daily closing prices of the SET50 index and the prices of stock options, which can be used to construct the implied volatility index for Thailand. The sample period covers the November 2010-December 2013 period with 634 observations. The scales of measurement of the series are indices. The autocorrelations functions from the correlogram analysis show no pattern of seasonality in the dataset. The change in the SET50 index, comprising 50 companies with large market capitalization from various equity sectors, is used as a proxy of the stock market return because the index is constructed to accommodate the issuing of options to be traded in the Stock Exchange of Thailand (SET).

We use the option pricing formula of Black and Scholes (1973) to compute the Thai implied volatility index. This formula is expressed as:

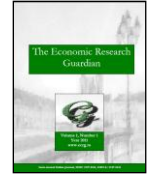$$C(S,t) = SN(d_1) - Xe^{-r(t-T)}N(d_2) \qquad (1)$$

where C is the call option price, S is the current stock price, X 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, $N(d_1)$ and $N(d_2)$, are normally distributed with a mean of zero and a standard deviation of one. These variables are specified as:

$$d_1 = [\ln(S/X) + (r + \frac{1}{2}v_S^2)^{(T-t)}]/v_S\sqrt{(T-t)} \qquad (2)$$

and

$$d_2 = d_1 - v_S\sqrt{(T-t)} \qquad (3)$$

where v_S is the volatility of the underlying stock price measured by its standard deviation. The expression $SN(d_2)e^{-r(T-t)}$ is the expected value that is equal to S_T if $S_T > X$ and zero otherwise. The function $N(d_2)$ is the probability that the option will be exercised so that $XN(d_2)$ is the striking price multiplied by the probability that the striking price will be paid. One parameter in the Black and Sholes pricing formula that cannot be directly observed is the volatility of the underlying stock price. Nevertheless, it is possible to compute such a volatility value that causes the option value to be consistent with the market price of an option. According to Watsham and Parramore (1997), we can calculate the implied volatility in the Thai stock market by plugging in the values of all parameters for the option pricing formula expressed in Eq. (1), including the option price that is available from the Thai option market. Then we use the iterative procedure to calculate the Thai VIX such that the option price obtained from the formula is equal to the actual option price observed in the option market. Since the established volatility is the implied volatility for each individual option at each

exercise price, the implied volatility index are computed as an average of all individual implied volatilities from the at-the-money 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. The results found by Christensen and Prabala (1998) provide an empirical justification for the common practice of interpreting the Black-Scholes implied volatility as a volatility forecast, not just a convenient means of quoting option prices. In addition, Dennis et al. (2006) find evidence indicating that implied volatilities are good proxies of expected stock volatilities. Hibbert et al. (2008) also indicate that it is advantageous to use the VIX to examine the return-volatility relationship compared to the use of realized volatility.

Table 1- Descriptive and unit root test statistics of the return and the change in implied volatility (November 19,2010-December 27, 2013)

|	r_t	Δv_t
Mean	0.0004	-2.70E05
Median	0.0015	-0.0004
Maximum	0.0758	0.2280
Minimum	-0.0910	-0.1686
Standard deviation	0.0144	0.0295
Skewness	-0.0144	0.9373
Kurtosis	7.7442	19.5125
Jarque-Bera statistic	612.890	7,284.159
First-order autocorrelation	-0.051	-0.334
ADF statistic (constant only)	-26.283 [0]	-16.752 [3]
	(0.000)	(0.000)
ADF statistic (constant and trend)	-26.272 [0]	-16.738 [3]
	(0.000)	(0.000)

Note: The series r and Δv are the return and the change in implied volatility index, respectively. The number in bracket is the optimal lag length determined by Akaike information criterion. The number in parenthesis is the probability of accepting the null hypothesis of unit root.

The descriptive statistics and unit root test statistics of the return and the change in implied volatility index are reported in Table 1. The mean of daily SET50 index return is small and very close to zero.
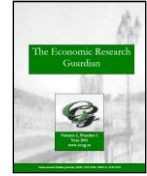
The return series is positively skewed and leptokurtic. The Jarque-Bera statistic indicates that the return series is not normally distributed. For the change in implied volatility index, the mean is negative but very close to zero while the series is positively skewed and leptokurtic. This series is also not normally distributed. Both series exhibit negatively serially correlation as shown by the first-order autocorrelation coefficients, which suggest that there are mean reversion processes. In addition, the ADF tests for the test with a constant only and with a constant and a linear trend are used to test for unit root. The test statistics reject the null hypothesis of unit root in both daily SET50 index return and the change in the Thai implied volatility index. Therefore, the test results indicate that both series are stationary. As a result, OLS estimates should be applicable to investigate the return-implied volatility relationship, which will be described in the next sub-section.

The evolutions of the implied volatility index and the equity index series are shown in Figure 1.
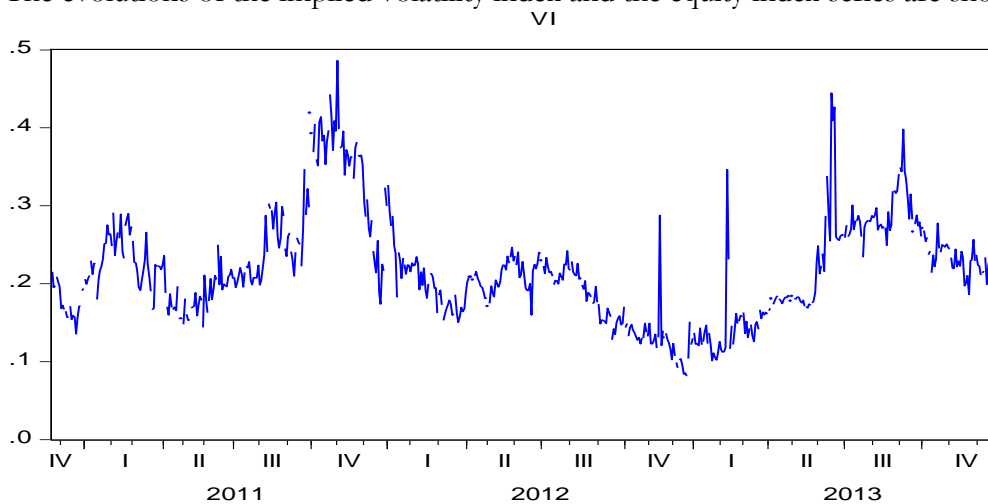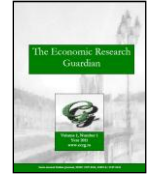

(a) Implied volatility index series
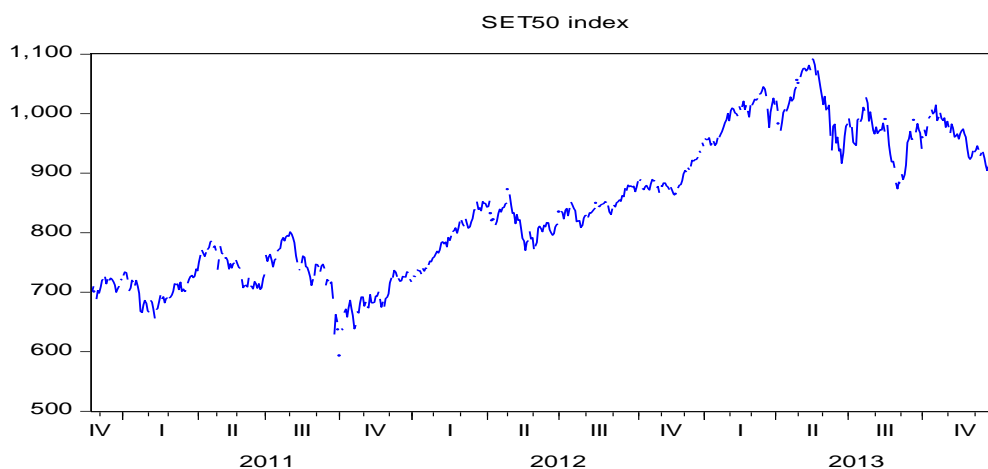
(b) SET50 index series

Figure 1 - Daily prices of implied volatility and SET50 (November 19, 2010-December 27, 2013).

The stock index series seems to exhibit a rising trend while the implied volatility index shows no trend. The stock index is highest at the beginning of the third quarter of 2013 and lowest during the third and fourth quarter of 2011. The implied volatility index exhibits at least two peaks during the period of investigation.

2.2. Empirical Models

The simplest way of investigating the relationship between the change in implied volatility index and the underlying equity index return is a simple regression of stationary series expressed as:

$$\Delta v_t = a_0 + a_1 r_t + e_t \tag{4}$$

where Δv is the change in implied volatility index, and r is the equity index return. Theoretically, the coefficient a_0 should be insignificant and the coefficient a_1 should be significantly negative. However, there are both positive and negative return shocks in the stock market that can be separated. Thus the equation that can be used to test for the asymmetric effect of positive and negative return can be expressed as:

$$\Delta v_t = \alpha_0 + \alpha_1 r(+)_t + \alpha_2 r(-)_t + \alpha_3 \Delta v_{t-1} + e_t \tag{5}$$

where r(+) denotes positive return and r(-1) denotes negative return. The inclusion of lagged change in implied volatility gives a room to test for the possibility of mean reversion in the change in implied volatility. If the model in Eq. (5) is correct, the intercept term should not be significantly different from zero. In other words, the mean of the change in implied volatility index should be zero. Moreover, the two coefficients in the model should be significantly different from zero with different sizes. The model in Eq. (5) is used by Siriopoulos and Fassas (2012) who do not include the lagged change in implied volatility in the equation.
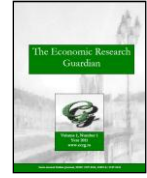
Other models that are used by Ederington and Guan (2010) to test for the relationship of the change in implied volatility with equity index return can be expressed as:

$$\Delta v_t = \alpha_0 + \alpha_1 r_t + \alpha_2 r(-)_t + \alpha_3 r_{t-1} + \alpha_4 \Delta v_{t-1} + e_t \tag{6}$$

and

$$\Delta v_t = \alpha_0 + \alpha_1 r_t + \alpha_2 r(-)_t + \alpha_3 r_{t-1} + \alpha_4 \Delta v_{t-1} + \alpha_5 r_t^2 + e_t \tag{7}$$

In Eqs. (6) and (7), *r(-1)* is equal to *r* if *r* is less than zero and zero otherwise. The negative coefficient of *r(-1)* indicates the asymmetric impacts of negative and positive return shocks, i. e., the implied volatility tends to increase more following a negative return than it falls following a positive return.

The lagged return is included to test for the possibility of lags or reversals in the relationship. If the coefficient of the squared return (r^2) is significantly negative for the model in Eq. (7), the relationship is non-linear and the size effect is present. However, the insignificant coefficient of squared return indicates that the models in Eqs. (6) and (7) are the same.

Some hypotheses can be tested using our specified empirical models mentioned above. The first hypothesis is that contemporaneous return on the SET50 index is negatively related to the change in the current Thai VIX as specified in Eq. (4). If this hypothesis does not hold, then the leverage or volatility feedback effects can explain the return-volatility relation. The second hypothesis that negative return imposes a larger impact on the change in the current Thai VIX than positive return does. This hypothesis can be tested using Eqs. (5)-(7). The third hypothesis posits that lagged return on the SET50 index is an important determinant used by the stock market to determine the change in the current implied volatility. If the coefficient of lagged return is insignificant, then the leverage effect might not hold in daily data. This hypothesis can be tested using Eqs. (6) and (7). The last hypothesis is that the size effect in Eq. (7) might exist. The insignificant coefficient of the squared return indicates the absence of the size effect and vice versa.

3. Empirical Results

In the present study, the Thai implied volatility index is considered to be a proxy for expected risk while the SET50 index is a proxy of the Thai stock market. The relationship between the change in implied volatility and stock index return are plotted as shown in Figure 2.
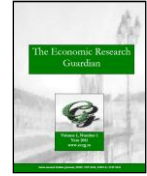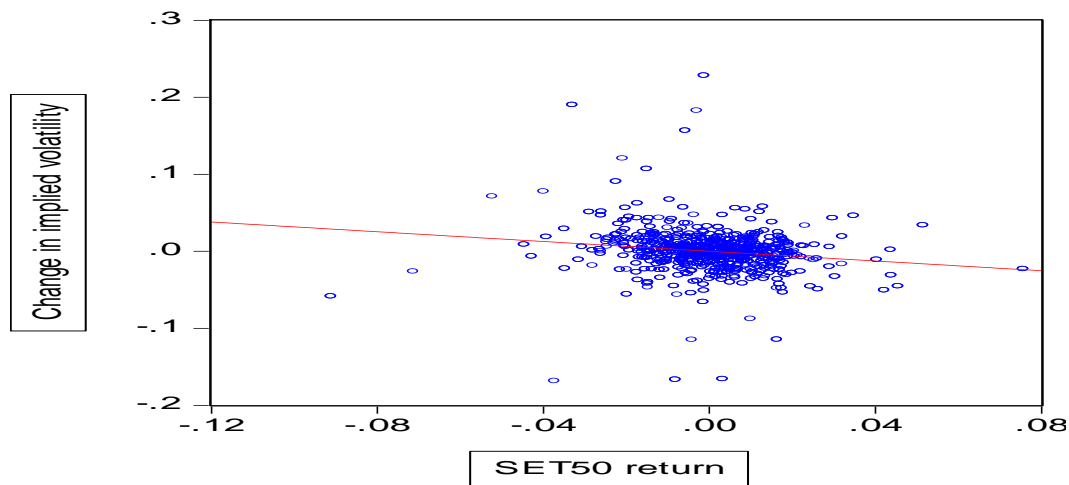

Figure 2 - Daily return of SET50 index and changes in implied volatility: November 19, 2011- December 27, 2013.

In Figure 2, the scattered diagram of daily SET50 return and the change in implied volatility suggests a negative relationship. The simple regression analysis of equation (4) gives the coefficient of

negative slope of -0.678 and is highly significant. However, the Durbin-Watson statistic is 2.639, which is substantially above 2 and thus indicates that there can be a negative serial correlation in the estimated equation. In other words, the estimated equation might not be valid.

Further regression analysis of the daily change in implied volatility index with the separated positive and negative returns expressed in Eq. (5) gives the results as shown in Table 2.

Table 2 - Results of the least square estimate of the change in implied volatility and separated positive and negative index returns

Dependent variable: Δv_t

|	Intercept	$r(+)_t$	$r(-1)_t$	Δv_{t-1}
Coefficient	-0.001	-0.275	-0.469	-0.364
	(0.617)	(0.050)	(0.000)	(0.000)

Adjusted R^2 = 0.143, F = 36.198, D-W = 2.142

Note: The number in parenthesis is the probability. Δv denotes the change in implied volatility index. r(+) denotes positive return while r(-) denotes negative return.

The results in Table 2 show that the estimated intercept in the OLS estimate is statistically insignificant or is zero. The mean of the change in Thai VIX of zero indicates that if the SET50 index does not change over the day, the change in respective implied volatility index should be very small. The estimated coefficient of the negative return is significant at the 1 percent level and larger than that of the positive return, which is significant at the 5 percent level. Specifically, if the SET50 index exhibits a negative return of 100 basis points or +1 percent, the implied volatility will rise by 0.469 percent. However, a positive return of the same size will cause smaller drop in implied volatility, i.e. the index exhibits a positive return of -1 percent, implied volatility index will drop by 0.275 percent. The Wald coefficient restriction test shows that the null hypothesis that the absolute value of the coefficient of the negative return is 1.5 times of that of the positive return cannot be rejected. Therefore, the negative return shocks impose a larger impact than the negative return shocks on implied volatility.[4] In addition, the highly significance of the negative coefficient of the one-day lag of the change in implied volatility index suggests the possibility that implied volatility index exhibits mean reversion.

The reaction of implied volatility to the market return shocks can also be shown by the OLS estimated results as shown in Table 3. Model 1 of Eq. (6) without the squared return is estimated first. The results show that the intercept is insignificant, which implies that the mean is zero and is consistent with the descriptive statistics reported in Table 1. The estimated coefficient of the current return is significant at the 5 percent level while the negative coefficient of the one-day lagged return

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[4] This evidence is compatible with the evidence found by Siriopoulos and Fassas (2012) who use the new method of computing the Greek implied volatility index.
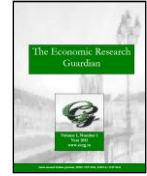
is insignificant. The highly significant and negative coefficient of lagged change in implied volatility suggests the possibility that the implied volatility is mean reverting.

Table 3 - The implied volatility reaction to market return shocks.

Dependent variable: Δv_t

	Intercept	r_t	$r(-1)_t$	r_{t-1}	Δv_{t-1}	r^2_t	Adj. R^2
Model 1	-4.36E-05	-0.355	-0.065	-0.170	-0.378	-	0.148
	(0.979)	(0.015)	(0.779)	(0.033)	(0.000)		
Model 2	-0.003	-0.110	-1.049	-0.191	-0.372	-10.591	0.156
	(0.128)	(0.630)	(0.018)	(0.017)	(0.000)	(0.009)	

Note: r denotes equity index return, r(-1) denote negative return.

However, the coefficient of current return is insignificant when the current squared return is included in Model 2 of Eq. (7). Moreover, the coefficient of lagged negative return is negative and significant at the 5 percent level. The significantly negative coefficient of r(-1) indicates that a negative shock imposes a stronger impact on the change in implied volatility than a positive shocks. The results confirm the results in Table 2. Nonetheless, the significant coefficient of current squared return indicates that there is evidence of non-linear relationship between the index return and implied volatility. The negative coefficient suggests that the relationship is convex. The quadratic term or squared return introduced by Giot (2005) is included in the regression of Model 2 in Table 3 in order to assess the size effect of the return. The significant coefficient of the quadratic term indicates that small and large returns can affect the changes in implied volatility index differently. It should be noted that Model 2 is superior to Model 1 because Model 1 does not take into account of the size effect that can affect the change in Thai VIX.

The main findings in our paper are worth discussing. First, the finding that the relationship between the change in implied volatility and its underlying index return is negative and asymmetric is in line with the findings by Black (1976), Christie (1982), Flemming et al. (1995), Whaley (2000), and Giot (2005) for advanced stock markets. This finding is also consistent with the findings by Tang(2007) for the Korean stock market, Frijins et al. (201) for Australian stock market, and Siriopoulos and Fassas (2012) for the Greek stock market. Second, the significant impact of the size effect in the Thai stock market is contradictory to the finding by Ederington and Guan (2010) for the US stock market. The overall results of our paper seem to support previous evidence of the negative and asymmetric risk-return relation.
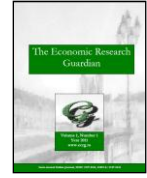
4. Conclusion

This paper attempts to examine the relationship between the Thai implied volatility changes and the underlying stock index return using daily data. The period of investigation is during November 19, 2010 and December 27, 2013. Given that the availability of index options traded in the Thai stock market, we compute the implied volatility index for the stock market, which can be called Thai VIX, from the Black and Sholes model using the prices of index options. The Black and Sholes formula enables us to obtain the implied volatility index with less computational complications compared with other available formulae. To our knowledge, this paper is the first attempt to obtain the asymmetric risk- return relation by employing the implied volatility index as a measure of risk in the Thai stock market.

The ordinary least square method is used. The regression results from stationary variables of the change in implied volatility index and the underlying stock index return reveal that the asymmetric relationship is found, which is consistent with the existing literature. In other words, negative return imposes a larger impact on implied volatility than does the negative return. Furthermore, the size effect is also observed. This size effect suggests that the size of the return does matter for the change in the Thai implied volatility index. The overall results give some implication for risk management. If negative return is associated with an asymmetrically larger rise in the implied volatility index, risk-averse investors who take the increased risk will require more compensation in terms of higher risk premium than those who do not want to take associated risk at all. Thus the finding also suggests that portfolio managers of investment companies should take into account of investors' reaction when they form their portfolios. In addition, policymakers should take into account measures that are able to prevent market manipulations that can cause unreasonable changes in the SET50 index so that investors and portfolio managers can effectively invest in the option market.
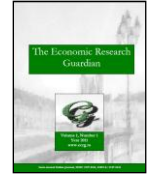
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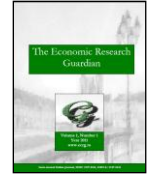
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