International Business Research; Vol. 10, No. 3; 2017
ISSN 1913-9004 E-ISSN 1913-9012
Published by Canadian Center of Science and Education

Does the CBOE Volatility Index Predict Downside Risk at the Tokyo Stock Exchange?

Chikashi Tsuji[1]

[1] Faculty of Economics, Chuo University, Japan

Correspondence: Chikashi Tsuji, Professor, Faculty of Economics, Chuo University, 742-1 Higashinakano, Hachioji-shi, Tokyo 192-0393, Japan. E-mail: mail_sec_low@minos.ocn.ne.jp

Received: December 15, 2016 Accepted: January 9, 2017 Online Published: January 10, 2017

doi:10.5539/ibr.v10n3p1 URL: http://dx.doi.org/10.5539/ ibr.v10n3p1

Abstract

This study investigates the predictability of the preceding day's US volatility index (VIX) from the Chicago Board Options Exchange (CBOE) for sharp price drops of the Tokyo Stock Price Index (TOPIX) by employing several versions of probit models. All our results indicate that the preceding day's US S&P 500 VIX movement has predictive power for sharp price declines of the TOPIX in Japan. As we repeatedly examined several left tail risks in TOPIX price changes and we also tested by applying some different versions of probit models, our evidence of the forecast power of the S&P 500 VIX for downside risk of the TOPIX shall be very robust.

Keywords: downside risk, probit model, stock market linkage, S&P 500, tail risk, TOPIX, VIX

1. Introduction

In a globalizing economy, much more academics and practitioners are paying attention to the research of international stock market connections. However, we note that many past investigations have been performed for overall stock market evolution, which contains all conditions or state of bull, bear, and ordinary markets (see, e.g., Diebold and Yilmaz, 2012; Wang, 2014). In light of this point, this study newly examines the international equity market linkages with a particular focus on the downward stock market condition.

More concretely, from the above new viewpoint, this study empirically tests the predictive power of the preceding day's US S&P 500 volatility index (VIX) from the Chicago Board Options Exchange (CBOE) for sharp price drops of the Tokyo Stock Price Index (TOPIX) by applying several versions of probit models. Our investigations employing US and Japanese financial market data reveal the following new findings. (1) First, the estimation results from our simple univariate probit model suggest that the dynamic evolution of the preceding day's US VIX has statistically significant predictive power for large TOPIX price drops in Japan. (2) Second, the estimation results from our autoregressive (AR)(3)-probit model also indicate that the preceding day's US VIX has statistically significant forecast power for large declines in TOPIX. (3) Finally, the estimation results from our probit model with different control variables again suggest that the preceding day's US VIX has statistically significant predictive power for the next day's sharp TOPIX price declines in Japan. The above new robust evidence from our examinations with new analyzing viewpoint is the contribution of this work.

Regarding the organization of the rest of this paper, Section 2 reviews previous studies; Section 3 explains our data and variables for our research; Section 4 documents our analyzing methodology; Section 5 supplies our empirical results; and Section 6 documents our interpretations and conclusions.

2. Literature Review

In this section, we concisely review existing literature focusing only on recent studies. Wang (2014) recently investigated the integration and causality relationships among six major East Asian stock markets, and this study also examined their interactions with the US market before and during the financial crisis from 2007 to 2009. Ülkü and Baker (2014) examined the connection between macroeconomic linkages and stock market linkages by inspecting the relations between macroeconomic betas and stock market betas.

Further, Chien et al. (2015) investigated the dynamic convergence process among cross-border equity markets in China and Association of Southeast Asian Nations (ASEAN) five countries applying a recursive cointegration analysis. Neaime (2016) investigated the contagion vulnerability, international financial relationships, and regional financial connections as to the Middle East and North Africa (MENA) equity markets. A recent study by

Mensi et al. (2016) examined the spillover effects between the US stock market and those of the BRICs (Brazil, Russia, India, China) and South Africa.

Laopodis (2016) studied the linkages of US seventeen industry returns, the US stock market, and several economic fundamental variables. As for the study in the context of downward stock markets, by focusing on the US stock market, Tsuji (2016) rigorously evidenced the superior forecast power of volatility forecasts derived from several kinds of generalized autoregressive conditional heteroskedasticity (GARCH) models (This paper can be downloaded from the journal's web site.). However, there seems to be little previous study that examined the forecast power of the US VIX for sharp drops of the Japanese stock market.

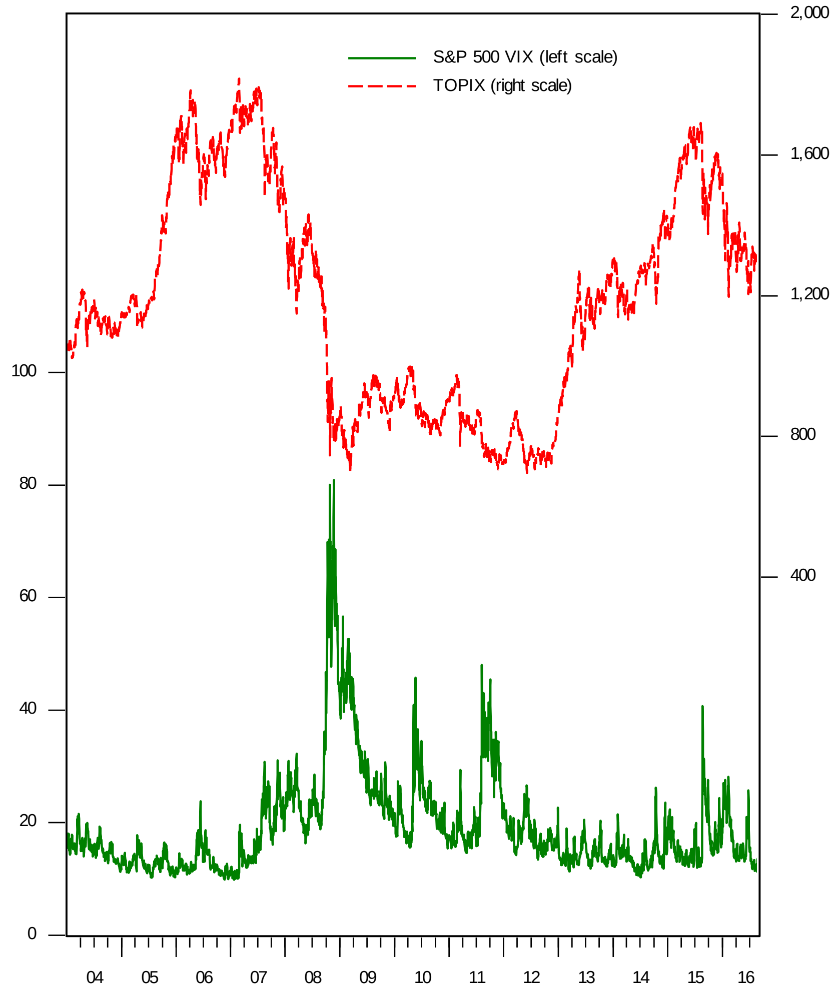

Figure 1. Dynamic daily evolution of the S&P 500 VIX and the TOPIX

3. Data and Variables

In this section, we describe our data and variables used in this study. First, DTPX means the first difference as to the price of the TOPIX in Japan, TPX. Next, DSPX denotes the first difference as to the level of the S&P 500 VIX in the US, SPX. Further, as control variables, we employ DTERM and DEX. More concretely, DTERM means the first difference series of the interest rate spread between the benchmark 10-year Japanese government bond yield and the Japanese three-month interbank offered rate. In addition, DEX denotes the first difference of the time-series as to the exchange rate of the Japanese yen to the US dollar.

All our data are daily time-series and the sample period examined in this work is from January 2, 2004 to September 5, 2016. The data source of all our data is Thomson Reuters. In Figure 1, we exhibit the daily time-series evolution of SPX and TPX for our sample period. This figure suggests that when the US VIX largely increases, the TOPIX sharply drops.

Table 1. Descriptive statistics of US and Japanese financial market variables

	SPX	DSPX	TPX
Mean	19.2034	−0.0019	1187.6160
Median	16.3050	−0.0500	1178.1150
Maximum	80.8600	16.5400	1816.9700
Minimum	9.8900	−17.3600	695.5100
Standard deviation	9.1309	1.7509	308.9502
Skewness	2.5594	0.6971	0.1989
Kurtosis	11.6955	22.4779	1.8700
Observations	3306	3306	3306
	DTPX	DTERM	DEX
Mean	0.0908	−0.0004	−0.0011
Median	0.0000	0.0000	0.0000
Maximum	115.4400	0.1365	3.3000
Minimum	−94.2300	−0.1305	−3.8500
Standard deviation	16.2202	0.0232	0.6601
Skewness	−0.4363	0.2107	−0.2993
Kurtosis	7.8679	5.6579	6.1150
Observations	3306	3306	3306

Note: DSPX means the first difference as to the US S&P 500 VIX, SPX. DTPX means the first difference as to the TOPIX in Japan, TPX. DTERM means the first difference as to the Japanese term spread and DEX denotes the first difference as to the exchange rate of the Japanese yen to the US dollar.

Table 2. Predictive power of the volatility index of the S&P 500 for large drops in the TOPIX: Results of univariate probit models

Panel A. 94% VaR			Panel B. 95% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.6642***	0.0000	Const.	−1.7558***	0.0000
DSPX(−1)	0.2203***	0.0000	DSPX(−1)	0.2117***	0.0000
McFadden R^2	0.102101		McFadden R^2	0.101639	
Panel C. 96% VaR			Panel D. 97% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.8573***	0.0000	Const.	−1.9983***	0.0000
DSPX(−1)	0.1972***	0.0000	DSPX(−1)	0.1954***	0.0000
McFadden R^2	0.097166		McFadden R^2	0.105178	
Panel E. 98% VaR			Panel F. 99% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−2.1875***	0.0000	Const.	−2.4454***	0.0000
DSPX(−1)	0.1923***	0.0000	DSPX(−1)	0.1612***	0.0000
McFadden R^2	0.122681		McFadden R^2	0.105014	

Note: DSPX(−1) means the first lag of the first difference as to the S&P 500 VIX in the US. McFadden R^2 denotes the McFadden's *R*-squared value. *** indicates the statistical significance at the 1% level.

4. Testing Methodology

In this section, we document our testing methodology. In this study, we employ three kinds of probit models to test the forecast power of the US S&P 500 VIX for sharp price drops in the TOPIX. It is emphasized that our repeated examinations with below different three probit models should be effective for robustness checks as to the predictability of the US VIX.

Our first model is the following simple univariate probit model:

$$DTPX_t = \pi_0 + \pi_1 DSPX_{t-1} + \mu_t, \quad (1)$$

$$y_t = \begin{cases} 1 & if\ \ DTPX \leq k\%VaR \\ 0 & otherwise \end{cases}.$$

In the above model (1), DTPX denotes the first diferrence of the TOPIX, DSPX denotes the first diferrence of the S&P 500 VIX, *k*% VaR means the *k*% Value at Risk, and *k* takes one of the values of 94, 95, 96, 97, 98, and 99 in our analyses (the same hereinafter). Hence, all our investigations test the predictive power of the US S&P 500 VIX for the downside tail risk in the price changes of the TOPIX in Japan.

Table 3. Predictive power of the volatility index of the S&P 500 for large drops in the TOPIX: Results of AR(3)-probit models

Panel A. 94% VaR			Panel B. 95% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.6744***	0.0000	Const.	−1.7640***	0.0000
DSPX(−1)	0.2147***	0.0000	DSPX(−1)	0.2060***	0.0000
DTPX(−1)	−0.0010	0.6347	DTPX(−1)	−0.0010	0.6610
DTPX(−2)	−0.0065***	0.0019	DTPX(−2)	−0.0054**	0.0129
DTPX(−3)	−0.0056***	0.0098	DTPX(−3)	−0.0054**	0.0181
McFadden R^2	0.113377		McFadden R^2	0.110992	
Panel C. 96% VaR			Panel D. 97% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.8680***	0.0000	Const.	−2.0291***	0.0000
DSPX(−1)	0.1875***	0.0000	DSPX(−1)	0.1847***	0.0000
DTPX(−1)	−0.0031	0.1872	DTPX(−1)	−0.0049*	0.0533
DTPX(−2)	−0.0049**	0.0351	DTPX(−2)	−0.0090***	0.0003
DTPX(−3)	−0.0059**	0.0146	DTPX(−3)	−0.0058**	0.0312
McFadden R^2	0.108797		McFadden R^2	0.131296	
Panel E. 98% VaR			Panel F. 99% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−2.2177***	0.0000	Const.	−2.4646***	0.0000
DSPX(−1)	0.1808***	0.0000	DSPX(−1)	0.1514***	0.0000
DTPX(−1)	−0.0048*	0.0978	DTPX(−1)	−0.0041	0.2441
DTPX(−2)	−0.0073***	0.0089	DTPX(−2)	−0.0055	0.1129
DTPX(−3)	−0.0067**	0.0288	DTPX(−3)	−0.0039	0.3059
McFadden R^2	0.147686		McFadden R^2	0.121501	

Note: DSPX(−1) means the first lag of the first difference as to the S&P 500 VIX in the US. DTPX(−*k*) means the *k*th lag of the first difference as to the TOPIX price in Japan. McFadden R^2 denotes the McFadden's *R*-squared value. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

The second model used in our tests is the following AR(3)-probit model (2):

$$DTPX_t = \kappa_0 + \kappa_1 DSPX_{t-1} + \sum_{k=1}^{3} \kappa_{k+1} DTPX_{t-k} + \omega_t, \tag{2}$$

$$y_t = \begin{cases} 1 & if \;\; DTPX \le k\%VaR \\ 0 & otherwise \end{cases}.$$

Further, our third model is the following multiple probit model:

$$\begin{aligned} DTPX_t = \tau_0 + \tau_1 DSPX_{t-1} + \tau_2 DTPX_{t-1} \\ + \tau_3 DTERM_{t-1} + \tau_4 DEX_{t-1} + \upsilon_t, \end{aligned} \tag{3}$$

$$y_t = \begin{cases} 1 & if \;\; DTPX \le k\%VaR \\ 0 & otherwise \end{cases}.$$

We note that in this third model (3), the first lags of DTPX, DTERM, and DEX are included as control variables.

Table 4. Predictive power of the volatility index of the S&P 500 for large drops in the TOPIX: Results of probit models with control variables

Panel A. 94% VaR			Panel B. 95% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.6638***	0.0000	Const.	−1.7552***	0.0000
DSPX(−1)	0.2180***	0.0000	DSPX(−1)	0.2089***	0.0000
DTPX(−1)	−0.0011	0.6507	DTPX(−1)	−0.0013	0.6082
DTERM(−1)	0.1783	0.9146	DTERM(−1)	0.8184	0.6410
DEX(−1)	−0.0053	0.9327	DEX(−1)	−0.0152	0.8174
McFadden R^2	0.102306		McFadden R^2	0.102071	
Panel C. 96% VaR			Panel D. 97% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−1.8583***	0.0000	Const.	−2.0039***	0.0000
DSPX(−1)	0.1894***	0.0000	DSPX(−1)	0.1837***	0.0000
DTPX(−1)	−0.0047*	0.0994	DTPX(−1)	−0.0062**	0.0463
DTERM(−1)	1.9036	0.3114	DTERM(−1)	1.2296	0.5608
DEX(−1)	0.0074	0.9165	DEX(−1)	−0.0139	0.8561
McFadden R^2	0.100184		McFadden R^2	0.111186	
Panel E. 98% VaR			Panel F. 99% VaR		
	Coefficient	*p*-value		Coefficient	*p*-value
Const.	−2.1952***	0.0000	Const.	−2.4524***	0.0000
DSPX(−1)	0.1792***	0.0000	DSPX(−1)	0.1483***	0.0000
DTPX(−1)	−0.0056	0.1138	DTPX(−1)	−0.0058	0.1749
DTERM(−1)	1.7384	0.4775	DTERM(−1)	2.0031	0.5194
DEX(−1)	−0.0627	0.4744	DEX(−1)	−0.0287	0.7910
McFadden R^2	0.130095		McFadden R^2	0.112172	

Note: DSPX(−1) means the first lag of the first difference as to the S&P 500 VIX in the US. DTPX(−*k*) means the *k*th lag of the first difference as to the TOPIX price in Japan. DTERM(−1) means the first lag of the first difference as to the Japanese term spread and DEX(−1) denotes the first lag of the first difference as to the exchange rate of the Japanese yen to the US dollar. McFadden R^2 denotes the McFadden's *R*-squared value. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

5. Empirical Results

First, we check some characteristics of the data used in this study. Table 1 exhibits the descriptive statistics of US and Japanese financial market variables we use in this research. Explaining by focusing on our two main variables of DSPX and DTPX, the mean value of DSPX is slightly negative while that of DTPX is slightly positive. In addition, from Table 1, we understand that the standard deviation value of DTPX is much higher than that of DSPX.

Next, we document our empirical results derived from the above-mentioned three probit models. First, the estimation results of our simple univariate probit model (1) are shown in Table 2. The results exhibited in panels A to F in Table 2 show that all the coefficients of the variable DSPX(−1) are statistically significantly positive at the 1% level. Hence, our first empirical results suggest that the preceding day's US S&P 500 VIX has statistically significant predictive power for large price drops of the TOPIX in Japan.

We next explain the estimation results with regard to our second model, the AR(3)-probit model (2). Table 3 exhibits the results and those displayed in all panels from A to F of this table suggest that again, all the coefficients of the variable DSPX(−1) are statistically significantly positive at the 1% level. Thus, the results derived from our second probit model also indicate that the preceding day's US S&P 500 VIX has statistically significant forecast power for sharp price declines in the TOPIX even though we include three AR variables as control variables in our analyzing model.

Finally, we document the estimation results as to our final probit model (3), in which we include the different control variables DTPX(−1), DTERM(−1), and DEX(−1). In Table 4, the estimation results are shown and again, all panels from A to F in this table indicate that all the coefficients of the variable DSPX(−1) are statistically significantly positive at the 1% level. The results in Table 4 therefore again demonstrate that the dynamic evolution of the preceding day's US VIX has statistically significant predictive power for the next day's sharp TOPIX drops in Japan even after we include different control variables in our testing econometric model.

As we documented above, we tested six tail risks in the form of 94% VaR, 95% VaR, 96% VaR, 97% VaR, 98% VaR, and 99% VaR in the distribution of the TOPIX price changes. In addition, we carefully performed our tests by employing three different versions of probit models. Therefore, we understand that all our test results consistently suggested that the increases of the preceding day's US S&P 500 VIX have statistically significant predictive power for large TOPIX price drops in Japan.

6. Summary and Conclusions

Using US and Japanese daily time-series data and applying three sorts of probit models, this study empirically tested the predictive power of the preceding day's US volatility index for the next day's sharp stock price drops in Japan. As we described in the previous section, all the results from our analyses suggested that the preceding day's US S&P 500 VIX has statistically significant predictive power for the next day's large price drops of the TOPIX in Japan. We note that because (1) we carefully examined several tail risks in the form of six kinds of VaR related to price changes in the TOPIX and (2) we also repeatedly conducted our tests by applying three different versions of probit models, we can naturally emphasize that our empirical results exhibited in this paper are highly robust.

In addition, demonstrating the interpretations of our work, our empirical results can be interpreted firstly that (1) downward asset price movements in the US and Japan, more specifically, downside risks in US and Japanese equity markets actually exhibit comovements. Further, our results also can be interpreted secondly that (2) there exist downside risk spillovers from the US equity market to the Japanese equity market (The spillovers in different contexts are also analyzed by Diebold and Yilmaz (2016) and MacDonald (2017), for example.).

It is also noted that these two viewpoints explored in this study are rather new and useful for further investigation and consideration of the issues related to international equity market linkages. Hence, it can be also emphasized that the findings from this study shall be important to further deepen our knowledge as to international stock market evolution and connections in a rapidly globalizing economy.

Acknowledgments

The author is particularly grateful to the repeated courteous invitation from the journal to write to this journal. The author also appreciates the Japan Society for the Promotion of Science Grant-in-Aid for Scientific Research for their generous financial assistance to this research. In addition, the author thanks the Editor and anonymous referees for their supportive and constructive comments on this paper. Moreover, the author also thanks Kevin Duran for his highly skillful editorial assistance to my paper. Finally, the author deeply thanks all the Editors of this journal for their care and kind attention on my paper.

References

Chien, M, S., Lee, C. C., Hu, T. C., & Hu, H. T. (2015). Dynamic Asian stock market convergence: Evidence from dynamic cointegration analysis among China and ASEAN-5. *Economic Modelling*, *51*, 84-98. http://dx.doi.org/10.1016/j.econmod.2015.06.024

Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, *28*, 57-66. http://dx.doi.org/10.1016/j.ijforecast.2011.02.006

Diebold, F. X., & Yilmaz, K. (2016). Trans-Atlantic equity volatility connectedness: U.S. and European financial institutions, 2004-2014. *Journal of Financial Econometrics*, *14*, 81-127. http://dx.doi.org/10.1093/jjfinec/nbv021

Laopodis, N. T. (2016). Industry returns, market returns and economic fundamentals: Evidence for the United States. *Economic Modelling*, *53*, 89-106. http://dx.doi.org/10.1016/j.econmod.2015.11.007

MacDonald, M. (2017). International capital market frictions and spillovers from quantitative easing. *Journal of International Money and Finance*, *70*, 135-156. http://dx.doi.org/10.1016/j.jimonfin.2016.08.003

Mensi, W., Hammoudeh, S., Nguyen, D. K., & Kang, S. H. (2016). Global financial crisis and spillover effects among the U.S. and BRICS stock markets. *International Review of Economics and Finance*, *42*, 257-276. http://dx.doi.org/10.1016/j.iref.2015.11.005

Neaime, S. (2016). Financial crises and contagion vulnerability of MENA stock markets. *Emerging Markets Review*, *27*, 14-35. http://dx.doi.org/10.1016/j.ememar.2016.03.002

Tsuji, C. (2016). Does the fear gauge predict downside risk more accurately than econometric models? Evidence from the US stock market. *Cogent Economics & Finance*, *4: 1220711*, 1-42. http://dx.doi.org/10.1080/23322039.2016.1220711

Ülkü, N., & Baker, S. (2014). Country world betas: The link between the stock market beta and macroeconomic beta. *Finance Research Letters*, *11*, 36-46. http://dx.doi.org/10.1016/j.frl.2013.07.002

Wang, L. (2014). Who moves East Asian stock markets? The role of the 2007−2009 global financial crisis. *Journal of International Financial Markets, Institutions & Money*, *28*, 182-203. http://dx.doi.org/10.1016/j.intfin.2013.11.003

Copyrights