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Cross Hedging Stock Sector Risk with Index Futures by Considering the Global Equity Systematic Risk

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Abstract: This article investigates the effectiveness of TAIEX (Taiwan Stock Exchange) futures, Taiwan 50 futures, and nonfinance nonelectronics subindex (NFNE) futures for cross hedging the price risk of stock sector indices traded on the Taiwan stock exchange. A state-dependent volatility spillover GARCH hedging strategy is developed to capture the regime switching global equity volatility spillover effect. Empirical results show that the NFNE futures exhibit superior effectiveness as an instrument for hedging stock sector exposures compared with the TAIEX and Taiwan 50 futures. Simultaneous hedge using both NFNE and MSCI (Morgan Stanley Capital International) world index futures further improves the hedging effectiveness compared with the hedging strategy using only the NFNE futures. This shows the importance of hedging the global equity systematic risk of stock sectors by considering the comovement between domestic and global equity markets.

Keywords: Markov regime switching; multiple futures hedging; volatility spillover; multivariate GARCH; cross hedging

JEL Classification: C32; C51; G10

1. Introduction

It is well documented that the joint distribution of spot and futures returns is time varying. The implication of the time-varying joint distribution property for futures hedging is that in implementing an optimal futures hedging strategy, the hedger has to estimate the time-varying minimum variance hedge ratio (MVHR) (Baillie and Myers 1991; Kroner and Sultan 1993; Park and Switzer 1995). A considerable number of studies have been devoted to investigating futures hedging effectiveness by estimating the time-varying MVHR with a variety of multivariate GARCH (Generalized AutoRegressive Conditional Heteroskedasticity) models (Gagnon and Lypny 1998; Brooks et al. 2002; Byström 2003; Lafuente and Novales 2003; Lee and Yoder 2007a; Fernandez 2008; Choudhry 2009; Arouri et al. 2011; Chang et al. 2011; Pan et al. 2014; Cifarelli and Paladino 2015; Lai and Lien 2017; Park and Shi 2017; Sukcharoen and Leatham 2017). A general finding is that dynamic futures hedging is superior to conventional static hedging using constant MVHR.

Sarno and Valente (2000, 2005a, 2005b) found that the dynamic relationship between spot and futures returns may be characterized by regime shifts. To account for the changing market condition in implementing the optimal dynamic hedging strategy, a variety of regime switching GARCH models have been developed to estimate the regime switching time-varying MVHR (Lee and Yoder 2007a, 2007b; Alizadeh et al. 2008; Lee 2009a, 2009b, 2010; Lee and Tsang 2011; Sheu and Lee 2014; Dark 2015;

Lai et al. 2017). In general, regime switching GARCH models exhibit superior hedging performance compared with their state-independent counterparts.

When hedging the price risk of a spot holding, hedgers normally apply the corresponding futures which are highly correlated with the underlying asset. When corresponding futures are not traded in the market, a closely related futures contract is required to implement the cross hedging strategy. For instance, Lee and Tsang (2011) considered a cross hedging strategy using American Depositary Receipts (ADRs) for hedging the price risk of individual stock. Adams and Gerner (2012) investigated the cross hedging performance of WTI (West Texas Intermediate), Brent, gasoil, and heating oil forwards to manage jet fuel spot price exposure. Ratner and Chiu (2013) examined the potential risk-reducing benefits of credit default swaps (CDS) against the price risk of the U.S. stock market sectors.

Taking into account the comovement between assets or markets might further improve futures hedging effectiveness. Fernandez (2008) analyzed a portfolio of metals traded on the London Metal Exchange and concluded that neglecting cross correlations leads to biased estimates of the optimal hedge ratios and the degree of hedging effectiveness. Lee and Tsang (2011) also found benefits of adding stock index futures in addition to ADRs for hedging single stock futures. Wu et al. (2011) investigated the volatility spillover effect from oil futures to corn spot and futures. They found that hedging performance is improved only marginally after adding additional crude oil futures to corn futures for hedging the corn spot exposure. The spillover model by Wu et al., however, does not account for the regime switching effect.

This paper investigates the performance of market index futures for the purpose of cross hedging the price risks of stock sector indices traded on the Taiwan stock exchange. Because there are no corresponding sector index futures for most of the sector indices traded on the Taiwan futures exchange, three domestic market indices futures—the TAIEX (Taiwan Stock Exchange) futures, the Taiwan 50 futures, and the nonfinance nonelectronics subindex (NFNE) futures—are applied to cross hedge the stock sector exposures. In this paper, we investigate the effectiveness of these futures as an instrument for cross hedging the price risk of stock sector holdings. Empirical results show that the NFNE futures exhibit superior hedging performance. We also consider simultaneous hedging using both NFNE and MSCI (Morgan Stanley Capital International) world index futures to hedge the domestic and global equity systematic risks of stock sectors with a regime switching volatility spillover GARCH (*RSVSG*) model.

The remainder of the article is organized as follows. The Markov regime switching volatility spillover GARCH (*RSVSG*) model is specified in Section 2. Section 3 presents the measurements of hedging performance, minimum variance hedge ratio (MVHR), and volatility spillover ratio. This is followed by discussions of data and empirical results. A conclusion ends the article.

2. Regime Switching Volatility Spillover GARCH (*RSVSG*) Model

This paper envisions a regime switching volatility spillover GARCH (*RSVSG*) model to hedge the price risk of stock sector holdings with both domestic and global stock index futures. *RSVSG* is an extension of the state-independent volatility spillover GARCH hedging model suggested by Wu et al. (2011) such that all system parameters are subject to regime shifting. The specification of *RSVSG* is given below:

Let $\mathbf{R}_t = \begin{bmatrix} r_{c,t} \\ r_{f,t} \end{bmatrix}$ denote a 2×1 vector of returns with $r_{c,t}$ and $r_{f,t}$ being the stock sector index returns and domestic stock index futures returns, respectively. Without considering the volatility spillover from the global stock market to the domestic market,

$$\mathbf{R}_t = \varepsilon_{t,s_t} \tag{1}$$

where $\boldsymbol{\varepsilon}_{t,s_t} = \begin{bmatrix} \varepsilon_{c,t,s_t} & \varepsilon_{f,t,s_t} \end{bmatrix}'$ is a vector of state-dependent shocks, "′" denotes transpose, and s_t stands for the state variable assumed to follow a first-order two-state Markov process with logistic transition probabilities function given by

$$\Pr(s_t = 1 | s_{t-1} = 1) = \frac{\exp(p_0)}{1 + \exp(p_0)} \tag{2}$$

$$\Pr(s_t = 2 | s_{t-1} = 2) = \frac{\exp(q_0)}{1 + \exp(q_0)} \tag{3}$$

where p_0 and q_0 are unconstrained parameters to be estimated along with unknown system parameters via maximum likelihood estimation. ε_{c,t,s_t} and ε_{f,t,s_t} are state-dependent idiosyncratic shocks of stock sector index and domestic stock index futures, respectively. Specifically,

$$\boldsymbol{\varepsilon}_{t,s_t} | \ \psi_{t-1} \quad \sim N(\mathbf{0}, \mathbf{H}_{t,s_t}) \tag{4}$$

where ψ_{t-1} is the information set available at time $t-1$ and $\mathbf{H}_{t,s_t}$ is a state-dependent conditional covariance matrix assumed to have a bivariate diagonal regime switching *BEKK* (Baba–Engle–Kraft–Kroner) GARCH (Engle and Kroner 1995) specification (Lee and Yoder 2007a) given by

$$\begin{aligned} \mathbf{H}_{t,s_t} = & \begin{bmatrix} h_{cc,t,s_t} & h_{cf,t,s_t} \\ h_{fc,t,s_t} & h_{ff,t,s_t} \end{bmatrix} = \begin{bmatrix} \gamma_{cc,s_t} & 0 \\ \gamma_{fc,s_t} & \gamma_{ff,s_t} \end{bmatrix}' \begin{bmatrix} \gamma_{cc,s_t} & 0 \\ \gamma_{fc,s_t} & \gamma_{ff,s_t} \end{bmatrix} + \\ & \begin{bmatrix} \alpha_{cc,s_t} & 0 \\ 0 & \alpha_{ff,s_t} \end{bmatrix}' \boldsymbol{\varepsilon}_{t-1} \boldsymbol{\varepsilon}'_{t-1} \begin{bmatrix} \alpha_{cc,s_t} & 0 \\ 0 & \alpha_{ff,s_t} \end{bmatrix} + \begin{bmatrix} \beta_{cc,s_t} & 0 \\ 0 & \beta_{ff,s_t} \end{bmatrix}' \mathbf{H}_{t-1} \begin{bmatrix} \beta_{cc,s_t} & 0 \\ 0 & \beta_{ff,s_t} \end{bmatrix} \end{aligned} \tag{5}$$

where h_{ii,t,s_t}, $i \in \{cc, ff\}$ are the volatilities of stock sector index and domestic stock index futures returns, respectively, and h_{cf,t,s_t} is the covariance of stock sector index and domestic stock index futures returns. Let $r_{W,t}$ be the world stock index futures returns given by

$$r_{W,t} = e_{W,t,s_t} = \sqrt{h_{W,t}} \varepsilon_{W,t,s_t} \tag{6}$$

where ε_{W,t,s_t} is the normalized state-dependent global stock shock and $h_{W,t}$ is the volatility of world stock index futures returns assumed to follow a regime switching GARCH(1,1) process:

$$h_{W,t,s_t} = \gamma_{W,s_t} + \alpha_{W,s_t} e^2_{W,t-1,s_t} + \beta_W h_{W,t-1,s_t}. \tag{7}$$

When we consider the volatility spillover from the global stock market to the domestic stock sector index and domestic stock index futures markets, Equation (1) is modified to

$$\mathbf{R}_t = \mathbf{e}_{t,s_t} + \boldsymbol{\varepsilon}_{t,s_t} \tag{8}$$

where $\mathbf{e}_{t,s_t}$ stands for the state-dependent shocks from the global market to domestic markets, specified as

$$\mathbf{e}_{t,s_t} = \begin{bmatrix} \varphi_{s_t} \\ \omega_{s_t} \end{bmatrix} e_{W,t,s_t} \tag{9}$$

and φ_{s_t} and ω_{s_t} are state-dependent volatility spillover parameters for the stock sector index and domestic stock index futures, respectively[1]. When we take into account both the effects of regime switching and global volatility spillover, Equations (2)–(9) constitute the specification of the regime

1 Because the state probability is time varying, φ_{s_t} and ω_{s_t} are also time varying after taking the weighted average using state probabilities.

switching volatility spillover GARCH (*RSVSG*). The variance and covariance dynamics in *RSVSG* are both state dependent and time varying and subject to the well-known path dependency problem. We follow the recombining procedures of Gray (1996) and Lee and Yoder (2007a) to solve the path dependency problem.

3. Measurements of Hedging Performance, Minimum Variance Hedge Ratio (MVHR), and Volatility Spillover Ratio

The hedging effectiveness (HE) is measured based on the percentage variance reductions of a hedging strategy over the unhedged position given by

$$HE = \frac{Var(r_{c,t}) - Var(r_{p,t})}{Var(r_{c,t})} \times 100 \tag{10}$$

where $Var(r_{p,t})$ and $Var(r_{c,t})$ are the variances of the hedged portfolio and the unhedged spot position, respectively. The return on hedged portfolio $r_{p,t}$ is equal to $r_{c,t} - \hat{\chi}_{f,t|t-1} r_{f,t}$ when the exposure on stock sector indices is hedged with only the domestic stock index futures and equal to $r_{p,t} = r_{c,t} - \hat{\chi}_{f,t|t-1} r_{f,t} - \hat{\chi}_{W,t|t-1} r_{I,t}$ when the exposure is hedged with both domestic stock index futures and world stock index futures. $\hat{\chi}_{f,t|t-1}$ and $\hat{\chi}_{W,t|t-1}$ are, respectively, the hedge ratios for domestic stock index futures and world stock index futures given by

$$\begin{bmatrix} \hat{\chi}_{f,t|t-1} \\ \hat{\chi}_{W,t|t-1} \end{bmatrix} = \begin{bmatrix} \frac{\hat{h}_{cf,t|t-1}\hat{h}_{W,t|t-1} - \hat{h}_{fW,t|t-1}\hat{h}_{cW,t|t-1}}{\hat{h}_{f,t|t-1}\hat{h}_{W,t|t-1} - \hat{h}_{fW,t|t-1}} \\ \frac{\hat{h}_{cW,t|t-1}\hat{h}_{f,t|t-1} - \hat{h}_{fW,t|t-1}\hat{h}_{cf,t|t-1}}{\hat{h}_{f,t|t-1}\hat{h}_{W,t|t-1} - \hat{h}_{fW,t|t-1}} \end{bmatrix} \tag{11}$$

where $\hat{h}_{f,t|t-1}$ and $\hat{h}_{W,t|t-1}$ are, respectively, the estimated conditional variances of domestic stock index futures and world stock index futures and $\hat{h}_{ij,t|t-1}$, $i, j \in \{c, f, W\}$ is the estimated conditional covariance of asset i and asset j.

We also compare the economic benefits of different hedging models using a mean–variance expected utility function (Kroner and Sultan 1993; Gagnon and Lypny 1998; Lee and Yoder 2007a, 2007b; Sheu and Lee 2014; Lai et al. 2017) given by

$$E[U(r_{p,t})|\psi_{t-1}] = E[r_{p,t}|\psi_{t-1}] - \kappa Var(r_{p,t}|\psi_{t-1}) \tag{12}$$

where κ is the coefficient of absolute risk aversion and E stands for the expectation operator.

Because portfolio managers are usually more concerned about the variability of negative losses, the semivariance metric is employed to remove the effect of upside gains from the variance. Mathematically, this can be expressed as (Alizadeh et al. 2008)

$$sv(-) = \frac{1}{T}\sum_{t=1}^{T}\{\min(0, r_{p,t} - \tau)\}^2 \tag{13}$$

where T is the sample size and τ is the target return which is set to zero in order to distinguish between positive and negative realized portfolio returns. A short hedger is concerned about negative semivariance and a long hedger is concerned about positive semivariance.

According to Equations (8) and (9), under the assumption of no correlation between the normalized idiosyncratic shocks in domestic stock sector index and global stock index futures or between the normalized idiosyncratic shocks in domestic stock index futures and global stock index futures, the state-dependent conditional variances of domestic stock sector index and domestic stock index futures returns are given by

$$Var(r_{c,t}|\psi_{t-1}, s_t) = h_{c,t,s_t} + \varphi_{s_t}^2 h_{W,t,s_t} \tag{14}$$

$$Var\left(r_{f,t}|\psi_{t-1},s_t\right) = h_{f,t,s_t} + \omega_{s_t}^2 h_{W,t,s_t}. \tag{15}$$

The state-dependent spillover ratio measures the proportion of the variances of domestic markets caused by the volatility spillover from global market shocks under different market regimes. The state-dependent volatility spillover ratios for domestic stock sector index and domestic stock index futures are respectively given by

$$VR_{c,t,s_t} = \frac{\varphi_{s_t}^2 h_{t,W,s_t}}{h_{t,c,s_t} + \varphi_{s_t}^2 h_{t,W,s_t}} \tag{16}$$

$$VR_{f,t,s_t} = \frac{\omega_{s_t}^2 h_{t,W,s_t}}{h_{t,f,s_t} + \omega_{s_t}^2 h_{t,W,s_t}}. \tag{17}$$

Accordingly, the correlation between global stock index futures and domestic stock sector index and the correlation between global stock index futures and domestic stock index futures are respectively given by

$$\rho_{cW,t,s_t} = \frac{1}{\sqrt{\frac{h_{c,t,s_t}}{\varphi_{s_t}^2 h_{W,t,s_t}^2} + 1}} \tag{18}$$

$$\rho_{fW,t,s_t} = \frac{1}{\sqrt{\frac{h_{f,t,s_t}}{\omega_{s_t}^2 h_{W,t,s_t}^2} + 1}}. \tag{19}$$

4. Data Description and Empirical Results

The proposed regime switching volatility spillover GARCH (*RSVSG*) model was applied to the local contracts of TAIEX futures, Taiwan 50 futures, nonfinance nonelectronics subindex (NFNE) futures and global MSCI world index futures to hedge the spot exposure of Taiwan stock sector indices including textiles, communication and internet, transportation, retailing, automobiles, and plastics and chemicals. Spot and futures prices are Wednesday closing prices obtained from Datastream for the period from 20 May 2009 to 28 December 2016 to match the earliest available data for MSCI world index futures. All data are denominated in USD in line with the currency of global MSCI world index futures. Estimation of all models was conducted using data for up to 2015 (inclusive) and the remaining data were used for out-of-sample analysis. Returns of each price series were computed as the changes in the natural logarithms of prices multiplied by 100. We compared the hedging performance of the trivariate regime switching volatility spillover GARCH (*RSVSG*) model with those of the state-independent trivariate volatility spillover GARCH (*VSG*) and the state-independent bivariate BEKK GARCH, which does not account for the volatility spillover effect. We investigated whether simultaneous hedging by adding additional MSCI world index futures under regime switching improves futures hedging effectiveness.

Table 1 shows the summary statistics of spot and futures returns. Most of the unconditional mean returns are positive and quite small. The automobile industry has the largest unconditional mean return among all data investigated with a value of only 0.246%. The automobile industry, however, has the largest return volatility with a standard deviation of 3.867. According to the skewness, leptokurtosis, and significant Jarque–Bera statistics, the unconditional distributions of spot and futures returns are all asymmetric, fat-tailed, and non-Gaussian. This justifies the importance of modelling the spot and futures returns with more flexible regime switching GARCH models.

Table 2 shows the estimates of unknown parameters of the *RSVSG* using both NFNE and MSCI world index futures. p_0 and q_0 are the parameters of the logistic transition probabilities functions. Take textiles, for instance; the estimates of p_0 and q_0 are 2.829 and 1.954, respectively. According to Equations (2) and (3), the transition probability from low volatility state to high volatility state is 0.587 and the transition probability from high volatility state to low volatility state is 0.179. Figure 1 shows the regime probabilities of being in State 1. In the covariance equation, the persistence in volatility is measured with $\alpha^2_{ii,s_t} + \beta^2_{ii,s_t}$, $i \in \{c, f\}$ and $s_t \in \{1, 2\}$. For textiles, $\alpha^2_{cc,1} + \beta^2_{cc,1}$ and $\alpha^2_{cc,2} + \beta^2_{cc,2}$ are, respectively, 0.349 and 0.184, and $\alpha^2_{ff,1} + \beta^2_{ff,1}$ and $\alpha^2_{ff,2} + \beta^2_{ff,2}$ are, respectively, 0.745 and 0.045. The volatility persistence of textiles spot and NFNE futures is higher in the low volatility state (State 1). Figures 2 and 3 show the state-dependent volatilities of textiles spot and NFNE futures, respectively. The average volatilities are, respectively, 2.020 and 3.781 for textiles spots in the low and high volatility states and are, respectively, 1.833 and 2.633 for NFNE futures in the low and high volatility states.

Table 1. Summary statistics of weekly returns (in percentages).

	Textiles	**Communication and Internet**	**Transportation**	**Retailing**
Mean	0.086	0.028	−0.111	0.147
Maximum	9.232	6.265	7.658	9.363
Minimum	−11.979	−8.869	−11.430	−11.416
SD	2.953	2.171	2.938	2.727
Skewness	−0.478	−0.414	−0.437	−0.317
Kurtosis	4.548	4.679	4.293	4.333
Jarque–Bera	54.808 ***	57.960 ***	40.306 ***	36.042 ***
	Automobile	Plastics and Chemicals	TAIFEX Futures	Taiwan 50 Futures
Mean	0.246	0.114	0.085	0.106
Maximum	12.810	8.512	6.392	6.540
Minimum	−14.360	−11.618	−10.015	−10.328
SD	3.867	2.786	2.560	2.588
Skewness	−0.279	−0.478	−0.546	−0.330
Kurtosis	3.940	4.605	3.897	3.493
Jarque–Bera	19.770 ***	57.683 ***	33.023 ***	11.215 ***
	Taiwan NFNE Futures	MSCI World Index Futures		
Mean	0.090	0.192		
Maximum	7.668	7.941		
Minimum	−9.659	−10.044		
SD	2.579	2.173		
Skewness	−0.490	−0.577		
Kurtosis	4.113	5.134		
Jarque–Bera	36.371 ***	97.375 ***		

Note: *** indicates significance at the 1% level and returns (in percentage) are calculated as the differences in the logarithm of prices multiplied by 100. NFNE, MSCI, and TAIEX stand for nonfinance nonelectronics subindex, Morgan Stanley Capital International and Taiwan Stock Exchange, respectively.

Table 2. Estimates of unknown parameters of the regime switching volatility spillover GARCH ($RSVSG$). Data estimation period is from 20 May 2009 to 30 December 2015.

	Textiles	**Retailing**	**Transportation**		**Textiles**	**Retailing**	**Transportation**
		Transition Probability				Spillover Equation	
p_0	2.829	1.525	0.653	γ_{W1}	1.137	0.000	0.000
	(0.399) ***	(0.576) ***	(0.430) *		(0.463) ***	(0.041)	(0.083)
q_0	1.954	−0.352	1.332	α_{W1}	0.240	0.270	0.166
	(0.566) ***	(0.453)	(0.468) ***		(0.098) ***	(0.126) **	(0.082) ***
		Covariance Equation		β_{W1}	0.242	0.544	0.379
γ_{cc1} [3]	−1.270	0.152	1.165		(0.154) *	(0.085) ***	(0.094) ***
	(0.396) ***	(0.531)	(0.267) ***	φ_1	0.768	0.600	0.495
γ_{cc2}	3.604	1.480	2.277		(0.086) ***	(0.080) ***	(0.107) ***
	(0.414) ***	(0.765) **	(0.859) ***	ω_1	0.763	0.719	0.391
γ_{cf1}	−0.418	0.377	1.203		(0.071) ***	(0.074) ***	(0.112) ***
	(0.293) *	(0.282) *	(0.210) ***	γ_{W2}	7.291	3.046	1.314
γ_{cf2}	2.313	0.657	2.317		(2.446) ***	(5.129)	(0.649) ***
	(0.302) ***	(0.585)	(0.199) ***	α_{W2}	0.220	0.000	0.118
γ_{ff1}	0.014	0.001	−0.002		(0.153) *	(0.039)	(0.086) *
	(0.059)	(0.040)	(0.076)	β_{W2}	0.049	1.000	0.874

Table 2. *Cont.*

	Textiles	**Retailing**	**Transportation**		**Textiles**	**Retailing**	**Transportation**
γ_{ff2}	1.158	0.002	0.245		(0.284)	(1.212)	(0.185) ***
	(0.510) ***	(0.022)	(0.974)	φ_2	0.544	0.775	0.701
α_{cc1}	0.000	0.021	0.038		(0.131) ***	(0.168) ***	(0.090) ***
	(0.035) **	(0.056)	(0.065)	ω_2	0.739	0.844	0.841
α_{cc2}	−0.029	−0.050	0.000		(0.092) ***	(0.138) ***	(0.073) ***
	(0.163)	(0.147)	(0.04)				
α_{ff1}	0.000	0.080	−0.076				
	(0.049)	(0.071)	(0.087)				
α_{ff2}	−0.145	0.066	0.000				
	(0.128)	(0.153)	(0.018)				
β_{cc1}	0.591	0.781	0.236				
	(0.194) *	(0.075) ***	(0.210)				
β_{cc2}	0.428	1.365	−0.835				
	(0.269) ***	(0.155) ***	(0.332) ***				
β_{ff1}	0.863	0.845	−0.169				
	(0.050) *	(0.057) ***	(0.315)				
β_{ff2}	−0.156	1.286	0.091				
	(0.303) ***	(0.135) ***	(0.571)				
LL [2]	−1797.51	−1781.97	−1827.45				
	Communication and Internet	Automobile	Plastics and Chemicals		Communication and Internet	Automobile	Plastics and Chemicals
		Transition Probability				Spillover Equation	
p_0	1.624	2.208	1.463	γ_{W1}	0.000	0.000	0.000
	(1.122) *	(0.829) ***	(0.485) ***		(0.050)	(0.080)	(0.076)
q_0	0.001	−0.013	0.026	α_{W1}	0.234	0.196	0.279
	(0.036)	(0.098)	(0.202)		(0.114) **	(0.224)	(0.198) *
		Covariance Equation		β_{W1}	0.579	0.593	0.512
γ_{cc1} [3]	(0.564)	0.163	0.711		(0.188) ***	(0.147) ***	(0.102) ***
	(0.691)	(0.768)	(0.340) **	φ_1	0.436	0.863	0.760
γ_{cc2}	2.729	2.936	2.172		(0.058) ***	(0.110) ***	(0.078) ***
	(0.520) ***	(1.434) **	(0.699) ***	ω_1	0.781	0.688	0.725
γ_{cf1}	0.424	0.093	0.743		(0.094) ***	(0.067) ***	(0.074) ***
	(0.282) *	(0.514)	(0.475) *	γ_{W2}	2.976	5.378	2.880
γ_{cf2}	1.868	0.785	1.173		(9.570)	(18.033)	(8.560)
	(1.070) ***	(0.211) ***	(0.376) ***	α_{W2}	0.000	0.128	0.000
γ_{ff1}	−0.001	0.000	0.000		(0.035)	(0.316)	(0.040)
	(0.031)	(0.030)	(0.115)	β_{W2}	1.000	0.872	1.000
γ_{ff2}	0.516	0.000	0.228		(2.055)	(4.023)	(2.150)
	(3.655)	(0.044)	(1.430)	φ_2	0.485	1.048	0.949
α_{cc1}	−0.075	0.014	0.120		(0.137) ***	(0.264) ***	(0.147) ***
	(0.121)	(0.033)	(0.081) *	ω_2	0.727	0.897	0.794
α_{cc2}	0.485	−0.010	0.185		(0.204) ***	(0.116) ***	(0.122) ***
	(0.273) **	(0.104)	(0.121) *				
α_{ff1}	−0.130	0.063	0.072				
	(0.120)	(0.083)	(0.091)				
α_{ff2}	0.153	−0.129	0.098				
	(0.265)	(0.106)	(0.102)				
β_{cc1}	0.662	0.853	0.699				
	(0.126) ***	(0.077) ***	(0.057) ***				
β_{cc2}	−0.395	1.278	0.990				
	(1.109)	(0.251) ***	(0.329) ***				
β_{ff1}	0.805	0.956	0.760				
	(0.124) ***	(0.031) ***	(0.063) ***				
β_{ff2}	0.948	1.089	1.162				
	(0.743)	(0.105) ***	(0.088) ***				
LL [2]	−1762.47	−1933.01	−1615.74				

[1] Figures in parentheses are standard errors and *, **, and *** indicate significance at the 10% level, 5% level, and 1% level, respectively; [2] LL stands for the log likelihood value; [3] State 1 is the low volatility state.

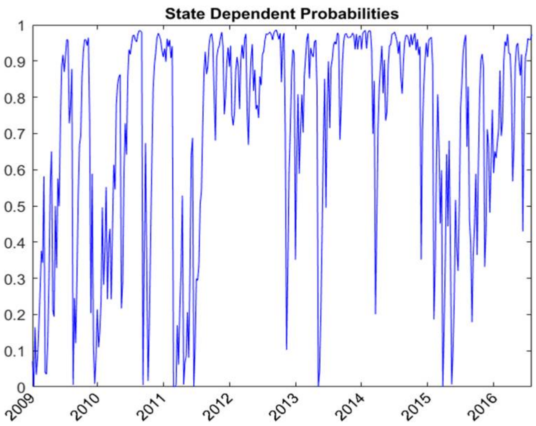

Figure 1. Regime probability of being in State 1 estimated with *RSVSG* for textiles.

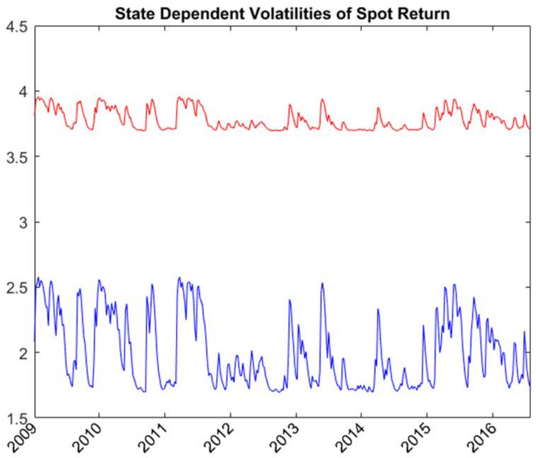

Figure 2. State-dependent volatilities of textiles spot returns estimated with *RSVSG*.

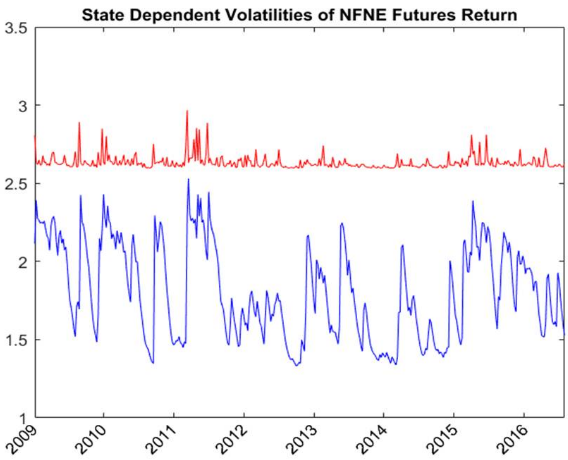

Figure 3. State-dependent volatilities of NFNE futures estimated with *RSVSG* for textiles.

The spillover equation shows the parameter estimates of the volatility dynamic of MSCI world index futures and the spillover factors φ_{s_t} and ω_{s_t}. Figure 4 shows the state-dependent volatilities of MSCI world index futures. The average volatilities are equal to 1.862 and 2.92 in the low and high volatility states, respectively. The state-dependent volatility spillover ratios defined in Equations (16) and (17) measure the state-dependent proportion of the variances of domestic markets caused by the volatility spillover from global market shocks. The state-dependent spillover ratio is a function of spillover factors, the volatility of domestic market, and the volatility of MSCI world index futures. Figures 5 and 6 show the state-dependent volatility spillover ratios of textiles spot and NFNE futures, respectively. The average volatility spillover ratios are, respectively, 0.409 and 0.275 for textiles spot in the low and high volatility states and are, respectively, 0.469 and 0.540 for NFNE futures in the low and high volatility states. The volatility spillover from the global market is higher in the NFNE futures than in the textiles spot for both regimes.

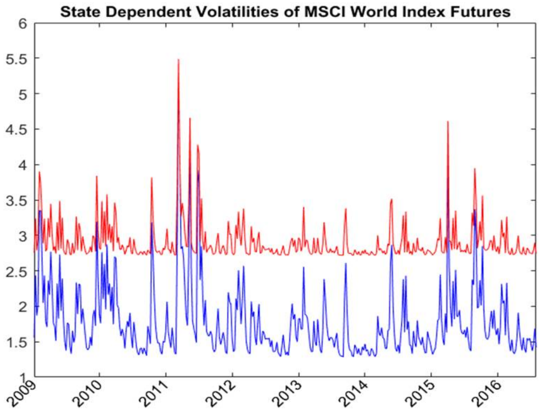

Figure 4. State-dependent volatilities of MSCI world index futures estimated with *RSVSG* for textiles.

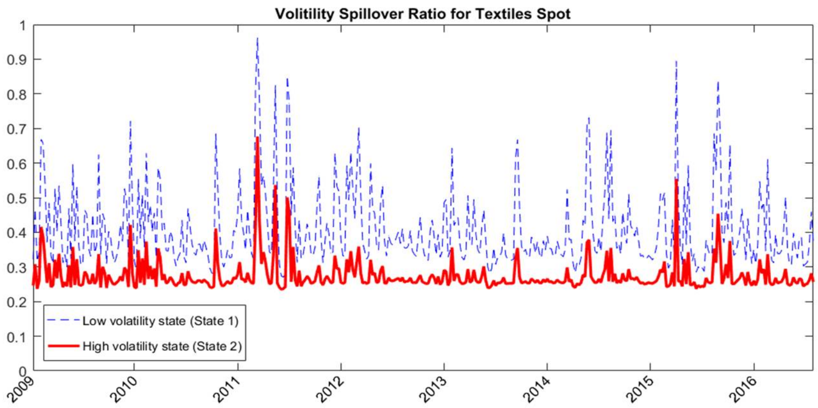

Figure 5. The state-dependent volatility spillover ratios for textiles spot estimated with *RSVSG.*

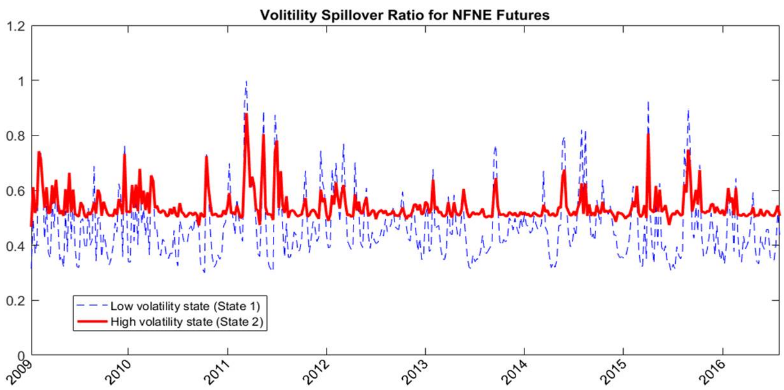

Figure 6. The state-dependent volatility spillover ratios for NFNE futures estimated with *RSVSG.*

Table 3 shows the out-of-sample hedging effectiveness without considering the effects of regime switching and volatility spillover. We compare the hedging performance of TAIEX futures, Taiwan 50 futures, and NFNE futures with the hedging strategy implemented with the state-independent bivariate BEKK GARCH model. Taking the textiles sector, for instance, the variance of the unhedged spot position is 6.745. When hedging the spot exposures with TAIEX futures, Taiwan 50 futures, and NFNE futures, the variances on hedged portfolio returns are 2.983, 3.198, and 2.966 or variance reductions of 55.78%, 52.59%, and 56.03%, respectively. Hedging the spot exposure on the textiles sector with NFNE futures exhibits the highest variance reductions: the improvements are 0.25% and 3.44% compared with the TAIEX and Taiwan 50 futures, respectively.

Adopting NFNE futures for hedging the spot exposure creates the highest variance reductions for textiles, transportation, automobile, and plastics and chemicals sectors. The Taiwan 50 futures create the highest variance reductions for the retailing sector and the communication and internet sector, and the TAIEX futures show poor hedging effectiveness. Overall, we find that the NFNE futures perform better than the Taiwan 50 and TAIEX futures. We further calculate the utility gains of hedging with NFNE futures. The hedger is assumed to have an expected utility function given by Equation (12) with the coefficient of absolute risk aversion κ equal to 4 (Lee 2009a, 2009b, 2010; Sheu and Lee 2014; Lai et al. 2017)[2]. Taking the textiles sector, for example, the utility gains of NFNE futures are 0.075 and 0.963 compared with the TAIEX and Taiwan 50 futures, respectively. Again, the NFNE futures create the highest utility gains for the textiles, transportation, automobile, and plastics and chemicals sectors. This is consistent with the results of the variance reductions.

Table 4 shows the out-of-sample hedging effectiveness of *RSVSG*. *RSVSG* captures the effects of both global volatility spillover and regime switching and hedges the spot exposures using both NFNE and MSCI world index futures. Figures 7 and 8 respectively show the hedge ratios of NFNE futures and MSCI world index futures for textiles estimated with *RSVSG*. Taking the textiles sector, for example, the variance of the unhedged spot position is equal to 6.745. When we apply the state-independent bivariate *BEKK* hedging strategy using only NFNE futures, the variance is 2.966—a variance reduction of 56.03%. If we take into account the volatility spillover effect from MSCI world index futures to domestic textiles sector and NFNE futures using a state-independent volatility spillover (*VSG*) model, the variance is 2.946—a variance reduction of 56.32%. Applying MSCI world index futures for hedging textiles spot exposure improves the hedging effectiveness. *VSG* is superior to *BEKK* for textiles, retailing, transportation, and communication and internet, but inferior to *BEKK* for automobiles and for plastics and chemicals. When we consider the effects of both volatility spillover and regime switching using both NFNE and MSCI world index futures, the variance of the hedged portfolio return by applying *RSVSG* is 2.930. The improvement by *RSVSG* in percentage variance reductions is 0.53% and 0.23% compared with the *VSG* and *BEKK* models, respectively. The incremental utility gains of *RSVSG* over *VSG* and *BEKK* are 0.135 and 0.053, respectively. Since most of the utility gains are positive for the data considered, hedging the stock sector exposure with additional MSCI world index futures under regime switching improves hedging effectiveness.

[2] Because all hedged portfolio returns are pretty small, the value of the expected utility is dominated by the second moment of the hedged portfolio return. Although it is not reported here, we find that hedging results are robust to the choice of the coefficient of absolute risk aversion for a wide range of κ ($\kappa = 1, 4, 20$). A hedging strategy with lower volatility has higher expected utility regardless the choice of the coefficient of absolute risk aversion.

Table 3. Out-of-sample hedging effectiveness without regime switching and global volatility spillover effects estimated with bivariate BEKK GARCH model.

	Variance of Hedged Portfolio Return	Percentage Variance Reduction [1]	Improvement of NFNE Futures over Other Futures [2]	Hedged Portfolio Returns	Expected Weekly Utility [3]	Utility Gain of NFNE Futures over Other Futures [4]
			Textiles			
Unhedged	6.745			0.086		
TAIEX	2.983	55.78%	0.25%	−0.457	−12.389	0.075
Taiwan 50	3.198	52.59%	3.44%	−0.485	−13.277	0.963
NFNE subindex	2.966	56.03%		−0.450	−12.314	
			Retailing			
Unhedged	4.481			0.147		
TAIEX	2.457	45.17%	−2.46%	−0.104	−9.932	−0.451
Taiwan 50	2.394	46.56%	−3.85%	−0.137	−9.714	−0.669
NFNE subindex	2.567	42.71%		−0.114	−10.383	
			Transportation			
Unhedged	5.132			−0.111		
TAIEX	2.028	60.49%	3.93%	−0.477	−8.588	0.815
Taiwan 50	2.127	58.56%	5.86%	−0.517	−9.025	1.252
NFNE subindex	1.826	64.42%		−0.468	−7.773	
			Communication and Internet			
Unhedged	3.166			0.028		
TAIEX	1.485	53.10%	−3.81%	0.006	−5.933	−0.474
Taiwan 50	1.238	60.91%	−11.62%	−0.035	−4.985	−1.422
NFNE subindex	1.606	49.29%		0.016	−6.407	
			Automobile			
Unhedged	6.921			0.246		
TAIEX	2.026	70.73%	2.34%	−0.394	−8.497	0.672
Taiwan 50	1.950	71.82%	1.25%	−0.439	−8.241	0.416
NFNE subindex	1.864	73.07%		−0.370	−7.825	
			Plastics and Chemicals			
Unhedged	4.404			0.114		
TAIEX	1.096	75.12%	11.85%	0.124	−4.258	2.095
Taiwan 50	1.054	76.06%	10.91%	0.068	−4.150	1.987
NFNE subindex	0.574	86.97%		0.133	−2.163	

Note: [1] Percentage variance reductions are calculated as the differences of the variance of unhedged position and the estimated variance of alterative models over the variance of unhedged position, multiplied by 100; [2] Improvement of NFNE futures over other futures is defined as the difference of the percentage variance reduction of hedging with NFNE futures and the percentage variance reduction of hedging with TAIEX futures and Taiwan 50 futures estimated with a bivariate BEKK GARCH model; [3] Expected weekly utility is calculated based on Equation (12); [4] Utility gain of NFNE futures over other futures is defined as the difference of the expected utilities of hedging with NFNE futures over the expected utilities of hedging with TAIEX futures and Taiwan 50 futures estimated with a bivariate BEKK GARCH model; [5] Estimation of all models was conducted using data from 20 May 2009 to 30 December 2015; the data from 6 January 2016 to 28 December 2016 were used for out-of-sample analysis.

Table 4. Out-of-sample hedging effectiveness evaluated with variance reduction and utility gain under regime switching and global volatility spillover effects.

	Variance of Hedged Portfolio Return	Percentage Variance Reduction [1]	Improvement of *RSVSG* over *VSG* and *BEKK* [2]	Hedged Portfolio Returns	Expected Weekly Utility [3]	Utility Gain of *RSVSG* over *VSG* and *BEKK* [4]
			Textiles			
Unhedged	6.745			0.086		
BEKK	2.966	56.03%	0.53%	−0.450	−12.314	0.135
VSG	2.946	56.32%	0.23%	−0.448	−12.233	0.053
RSVSG	2.930	56.56%		−0.458	−12.180	
			Retailing			
Unhedged	4.481			0.147		
BEKK	2.567	42.71%	4.36%	−0.114	−10.383	0.791
VSG	2.405	46.32%	0.74%	−0.102	−9.722	0.131
RSVSG	2.372	47.06%		−0.104	−9.591	
			Transportation			
Unhedged	5.132			−0.111		
BEKK	1.826	64.42%	−0.43%	−0.468	−7.773	−0.094
VSG	1.800	64.93%	−0.95%	−0.466	−7.664	−0.203
RSVSG	1.849	63.98%		−0.473	−7.867	
			Communication and Internet			
Unhedged	3.166			0.028		
BEKK	1.606	49.29%	2.05%	0.016	−6.407	0.244
VSG	1.554	50.93%	0.40%	−0.005	−6.220	0.057
RSVSG	1.541	51.33%		0.001	−6.162	
			Automobile			
Unhedged	6.921			0.246		
BEKK	1.864	73.07%	0.10%	−0.370	−7.825	0.023
VSG	1.977	71.43%	1.74%	−0.386	−8.294	0.492
RSVSG	1.857	73.17%		−0.375	−7.802	
			Plastics and Chemicals			
Unhedged	4.404			0.114		
BEKK	0.574	86.97%	−1.64%	0.133	−2.163	−0.300
VSG	0.710	83.88%	1.44%	0.106	−2.733	0.270
RSVSG	0.646	85.32%		0.123	−2.463	

Note: [1] Percentage variance reductions are calculated as the differences of the variance of unhedged position and the estimated variance of alterative models over the variance of unhedged position, multiplied by 100; [2] Improvement of *RSVSG* over *VSG* and *BEKK* is defined as the difference of the percentage variance reduction of hedging with *RSVSG* and the percentage variance reduction of hedging with *VSG* and *BEKK*; [3] Expected weekly utility is calculated based on Equation (12); [4] Utility gains of *RSVSG* over *VSG* and *BEKK* are defined as the differences of the expected utilities of hedging with *RSVSG* over the expected utilities of hedging with *VSG* and *BEKK*; [5] Estimation of all models was conducted using data from 20 May 2009 to 30 December 2015; data from 6 January 2016 to 28 December 2016 were used for out-of-sample analysis.

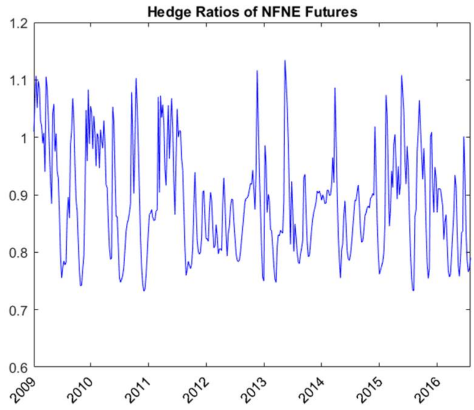

Figure 7. Hedge ratios of NFNE futures estimated with $RSVSG$ for textiles.

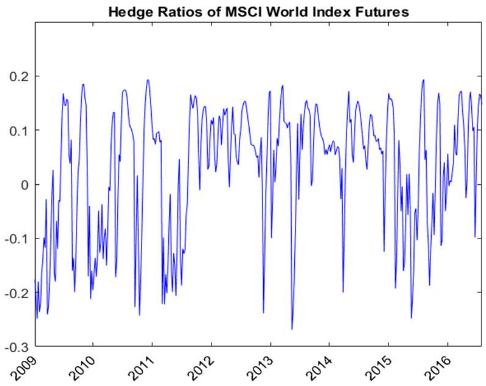

Figure 8. Hedge ratios of MSCI world index futures estimated with $RSVSG$ for textiles.

Because multiple futures hedging applies more futures contracts and is more costly to implement, we further investigate the superiority of $RSVSG$ over $BEKK$ and VSG by taking transaction costs into account. Taking textiles, for instance, if the hedger uses $BEKK$ hedging, the average weekly utility is $U_{BEKK} = -0.450 - 4(2.966) \approx -12.314$. With $RSVSG$ hedging, the average weekly utility is $U_{RSVSG} = -0.458 - 4(2.930) \approx -12.180$. The hedger's net benefit from using $RSVSG$ hedging over $BEKK$ hedging is equal to $U_{RSVSG} - U_{BEKK} - C = 0.135 - C$, where C stands for the net average weekly transaction cost. If $C < 0.135$ (in percentage) or 13.5 basis points, $RSVSG$ hedging is preferred to $BEKK$ hedging. Since the typical round trip transaction costs are around 0.03% (Lai et al. 2017), the net average weekly transaction cost between $RSVSG$ and $BEKK$ is defined as $C = \frac{1}{T}\sum_{t=1}^{T}(C_{RSVSG} - C_{BEKK})$, where $C_{RSVSG} = 0.03\% \times |\hat{\chi}_{f,t|t-1} - \hat{\chi}_{f,t-1|t-2}| + 0.03\% \times |\hat{\chi}_{W,t|t-1} - \hat{\chi}_{W,t-1|t-2}|$. Accordingly, the net average weekly transaction cost is equal to $0.03\% \times (0.046 + 0.055) - 0.03\% \times 0.017 = 0.00223\%$, or 0.223 basis points, which is smaller than 13.5 basis points. A mean–variance expected-utility-maximizing hedger would adopt $RSVSG$ hedging even after taking account of the transaction costs. Similarly, the net average weekly transaction cost between $RSVSG$ and VSG is equal to $0.03\% \times (0.046 + 0.055) - 0.03\% \times (0.021 + 0.017) = 0.00189\%$, or 0.189 basis points, which is smaller than 5.3 basis points, the net benefit from using $RSVSG$ hedging over VSG hedging.

Table 5 presents the hedging effectiveness evaluated with semivariance reduction and semi-utility gain under regime switching and global volatility spillover effects. Negative and positive semivariance reflect the downside variation of hedged portfolio for short and long hedgers' positions, respectively. Again, most of the incremental semi-utility gains of $RSVSG$ over VSG and $BEKK$ are positive. We reach the same conclusion that hedging the stock sector exposure with additional MSCI world index futures under regime switching improves hedging effectiveness.

Table 5. Out-of-sample hedging effectiveness evaluated with semivariance reduction and semi-utility gain under regime switching and global volatility spillover effects.

	Semivariance of Hedged Portfolio Return	Percentage Semivariance Reduction [1]	Improvement of *RSVSG* over *VSG* and *BEKK* [2]	Hedged Portfolio Returns	Expected Weekly Semi-Utility [3]	Semi-Utility Gain of *RSVSG* over *VSG* and *BEKK* [4]
Textiles						
Short hedgers' positions (negative semivariance)						
Unhedged	3.896			0.086		
BEKK	2.085	46.49%	0.80%	−0.450	−8.789	0.117
VSG	2.068	46.91%	0.38%	−0.448	−8.722	0.050
RSVSG	2.054	47.29%		−0.458	−8.672	
Long hedgers' positions (positive semivariance)						
Unhedged	2.779			0.086		
BEKK	1.027	63.06%	1.30%	−0.450	−4.556	0.136
VSG	1.010	63.67%	0.69%	−0.448	−4.487	0.067
RSVSG	0.991	64.36%		−0.458	−4.420	
Retailing						
Short hedgers' positions (negative semivariance)						
Unhedged	2.135			0.147		
BEKK	1.323	38.05%	7.26%	−0.114	−5.404	0.630
VSG	1.181	44.69%	0.62%	−0.102	−4.826	0.052
RSVSG	1.168	45.31%		−0.104	−4.774	
Long hedgers' positions (positive semivariance)						
Unhedged	2.265			0.147		
BEKK	1.208	46.66%	1.71%	−0.114	−4.947	0.165
VSG	1.174	48.18%	0.20%	−0.102	−4.798	0.016
RSVSG	1.169	48.38%		−0.104	−4.781	
Transportation						
Short hedgers' positions (negative semivariance)						
Unhedged	3.048			−0.111		
BEKK	1.318	56.78%	0.16%	−0.468	−5.738	0.015
VSG	1.291	57.65%	−0.71%	−0.466	−5.629	−0.094
RSVSG	1.313	56.94%		−0.473	−5.723	
Long hedgers' positions (positive semivariance)						
Unhedged	2.066			−0.111		
BEKK	0.692	66.49%	0.84%	−0.468	−3.237	0.064
VSG	0.689	66.65%	0.69%	−0.466	−3.222	0.049
RSVSG	0.675	67.33%		−0.473	−3.173	

Table 5. *Cont.*

	Semivariance of Hedged Portfolio Return	Percentage Semivariance Reduction [1]	Improvement of *RSVSG* over *VSG* and *BEKK* [2]	Hedged Portfolio Returns	Expected Weekly Semi-Utility [3]	Semi-Utility Gain of *RSVSG* over *VSG* and *BEKK* [4]
Communication and Internet						
Short hedgers' positions (negative semivariance)						
Unhedged	1.516			0.028		
BEKK	0.796	47.46%	0.04%	0.016	−3.170	−0.012
VSG	0.818	46.01%	1.49%	−0.005	−3.279	0.097
RSVSG	0.796	47.50%		0.001	−3.182	
Long hedgers' positions (positive semivariance)						
Unhedged	1.602			0.028		
BEKK	0.778	51.40%	3.55%	0.016	−3.098	0.213
VSG	0.713	55.50%	−0.55%	−0.005	−2.857	−0.029
RSVSG	0.722	54.95%		0.001	−2.885	
Automobile						
Short hedgers' positions (negative semivariance)						
Unhedged	4.012			0.246		
BEKK	1.323	67.01%	2.33%	−0.370	−5.664	0.370
VSG	1.412	64.81%	4.54%	−0.386	−6.033	0.739
RSVSG	1.230	69.34%		−0.375	−5.294	
Long hedgers' positions (positive semivariance)						
Unhedged	2.794			0.246		
BEKK	0.642	77.04%	0.68%	−0.370	−2.936	0.072
VSG	0.694	75.16%	2.57%	−0.386	−3.162	0.298
RSVSG	0.622	77.72%		−0.375	−2.865	
Plastics and Chemicals						
Short hedgers' positions (negative semivariance)						
Unhedged	2.044			0.114		
BEKK	0.219	89.27%	0.91%	0.133	−0.744	0.064
VSG	0.241	88.19%	1.99%	0.106	−0.860	0.179
RSVSG	0.201	90.18%		0.123	−0.680	
Long hedgers' positions (positive semivariance)						
Unhedged	2.385			0.114		
BEKK	0.361	84.85%	−0.93%	0.133	−1.312	−0.099
VSG	0.401	83.17%	0.75%	0.106	−1.500	0.088
RSVSG	0.383	83.92%		0.123	−1.411	

Note: [1] Percentage variance reductions are calculated as the differences of the variance of unhedged position and the estimated variance of alterative models over the variance of unhedged position, multiplied by 100; [2] Improvement of *RSVSG* over *VSG* and *BEKK* is defined as the difference of the percentage variance reduction of hedging with *RSVSG* and the percentage variance reduction of hedging with *VSG* and *BEKK*; [3] Expected weekly utility is calculated based on Equation (12); [4] Utility gains of *RSVSG* over *VSG* and *BEKK* are defined as the differences of the expected utilities of hedging with *RSVSG* over the expected utilities of hedging with *VSG* and *BEKK*; [5] Estimation of all models was conducted using data from 20 May 2009 to 30 December 2015; data from 6 January 2016 to 28 December 2016 were used for out-of-sample analysis.

5. Conclusions

There are two main questions investigated in this paper. First, because there are no corresponding sector futures for most sector indices traded on the Taiwan stock exchange, closely related futures must be applied for cross hedging the spot exposures on stock sectors. This article investigated the effectiveness of three potential futures as an instrument for cross hedging—TAIEX futures, Taiwan 50 futures, and NFNE futures. Second, since the domestic market is affected by global shocks and the shock spillover from the global market might depend on the state of market conditions, a regime switching volatility spillover GARCH hedging strategy was developed to investigate if simultaneous hedging using both domestic stock index futures and MSCI world index futures under regime switching increases hedging effectiveness.

Empirical results show that adopting NFNE futures for hedging the spot exposure creates the highest variance reductions for textiles, transportation, automobile, and plastics and chemicals sectors. TAIEX futures has the poorest hedging performance. Overall, we find that the NFNE futures perform better than the Taiwan 50 and TAIEX futures. Applying MSCI world index futures to capture the global stock systematic risk and hedging the spot exposures with both NFNE and MSCI world index futures improves hedging effectiveness. *VSG* is superior to *BEKK* for textiles, retailing, transportation, and communication and internet sectors. When we take into account the effects of both global volatility spillover and regime switching, the *RSVSG* hedging strategy exhibits superior hedging performance compared with the *VSG* and *BEKK* GARCH models. This shows the importance of hedging the stock sector price risks using both NFNE futures and MSCI world index futures implemented with a state-dependent volatility spillover model.

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Conflicts of Interest: The authors declare no conflict of interest.

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