Study on the Price Volatility Spillover Relationship between Stock Index Futures and Spot Market

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Abstract

This paper focuses on the linkage between stock indices and stock index futures in China and the United States. Firstly, a VAR-DCC-GARCH model is constructed to study the spillover effects between stock indices and stock index futures in China and the United States. Secondly, the empirical analysis is used to compare the data of stock indices and stock index futures in China and the United States, and it is finally concluded that there is a significant linkage between stock indices and stock index futures, and the linkage effect between CSI 300 stock index and stock index futures is significantly weaker than that between S&P 500 stock index and stock index futures.

Keywords

Volatility Spillover; Stock Index Futures; Stock Market; GARCH Model.

1. Introduction

As two important sub-markets in the capital market, the stock market and the futures market are interlinked and interdependent. The volatility and environment of the two markets are inevitably taken into account in the implementation of national financial policies and strategies, as well as in the formulation of investment decisions by listed companies. This paper mainly selects the contemporaneous data of stock indices and stock index futures of China and the United States as the research object, and further analyses the volatility spillover relationship between stock indices and stock index futures of the two countries respectively by constructing a VAR-DCC-GARCH model, and predicts the future development direction and trend of China's financial market according to the difference and connection between the two countries' financial markets.

The main objectives of the volatility spillover model are as follows: firstly, to determine the flow of information in the different financial markets of the two countries based on the volatility spillover relationship analysed by the model. Secondly, the volatility spillover model will provide insight into the linkages between the equity markets and the stock index futures markets of the two countries respectively. Thirdly, the primary and secondary relationships between stock indices and stock index futures in the transmission of information volatility can be explored in depth.

The main structure of this paper is as follows. The second section presents the existing literature on the relationship between stock indices and stock index futures. The third section provides a statistical description and analysis of the selected data. The fourth section presents the VAR-DCC-GARCH model in detail. The fifth part presents and analyses the empirical results. The sixth part concludes.

2. Literature Review

Martin (2015) proposes the stabilization hypothesis and the instability hypothesis, i.e. the hypothesis that futures markets reduce price volatility in the spot market and the hypothesis that futures markets increase price volatility in the spot market. Darrat (1995), Kamara (1992) and Pericli (1997) study the effect of S&P 500 futures on stock indices in the US. Bologna et al. (2002) investigate the relationship between stock indexes and stock index futures on the Italian stock exchange. Chang (1999) has conducted an in-depth analysis of the relationship between the Nikkei 225 index and its related spot market by examining that the prices in the spot market are not affected by price fluctuations in the futures market and are mainly influenced by economic Factors.Rubinstein (1987), Damodaran (1990), Harris (1989) and Antonios (1995) argues that price volatility in the futures market will increase price volatility in the spot market as speculators take advantage of the volatile relationship between the futures market and the spot market to obtain certain benefits. Related studies in China have been conducted by Marcel and Zhang (2020), Martin (2015) and Chen (2013) on the volatility impact of Chinese stock index futures on the spot market.

Ross (1989) argues that it is unreliable to attribute the increase in volatility in the spot market to the introduction of the futures market and that it may be due to the development of the futures market resulting in a fuller flow of information elements. Therefore, Kutan et al (2018), Yang (2014) and Tian Shuxi (2020) introduce positive feedback trading models in their study of the relationship between the two to explore the impact of futures markets on the spot market.

Wang (2017) studied the Shanghai and Shenzhen 300 stock indexes and the corresponding stock index futures in China and found that there is no obvious primary and secondary relationship between the two in the long term, and in the short term the futures market usually dominates the stock index market. The three periods of stability, prosperity and downturn are used to study the linkage between the Chinese stock index futures market and the spot market. Similar studies have been conducted by Xie (2014), Feng Sixian (2010) and Yang (2012).

Most of the research analysis in the existing literature is limited to a single financial market, with less research on comparisons between multiple financial markets. Kutan et al (2018) enter a positive feedback trading model and a GJR-GARCH model, while comparing empirical results between emerging and mature markets to conduct an analysis, where positive feedback trading is prevalent in emerging financial markets. Jin (2017) selects 16 different equity markets and studies the relationship between time-varying returns and volatility for these markets, finding strong persistence and non-stationary marginality in the volatility of equities. Aloui et al (2018) study in a similar manner to this paper. This paper focuses on data from China and the US, selected for the same time period, and focuses on the linkage, volatility spillover relationship between stock index futures and spot markets in China and the US over the same time period.

3. Data Selection and Methodology

This paper focuses on the volatility spillover relationship between stock indices and stock index futures as well as the linkage relationship. The models chosen are the DCC-GARCH model and the vector autoregressive (VAR) model. Further, the interaction between the price intensity and duration of the two is investigated. This paper mainly selects China's CSI 300 stock index futures contract and its stock index futures and the US S&P 500 and its stock index futures from January 5, 2015 to September 30, 2019 as the main research objects, excluding the data of mismatch between spot and futures and the data affected by the expiry date of the futures market, a total of 1152 sets of domestic data and 1193 sets of foreign data are obtained.

3.1. VAR Model

$$Y_t = \beta_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \varepsilon_t \tag{1}$$

$$Y_t = [\Delta S_t \quad \Delta H_t]' \tag{2}$$

Here ΔS_t is the difference of stock index prices in period t and ΔH_t is the difference of stock index futures prices in period t. β_n is a 2×2 matrix of parameters to be estimated. $\varepsilon_t=[\varepsilon_{1t} \quad \varepsilon_{2t}]'$, $E(\varepsilon_t) = 0, E(\varepsilon_t\varepsilon_t') = \sigma^2 . \varphi_t = (\varepsilon_{st} \quad \varepsilon_{ht})^T$ is the residual vector satisfying $\varphi_t|\Omega_{t-1} \sim N(0, V_t)$, where V_t is the conditional variance matrix.

We are not usually concerned with the final coefficient estimates when constructing a VAR model. as a valid method of causal analysis, the impulse response function can be used to analyse the relationship between variables. the residuals in a VAR model reflect the shocks to the internal model from the external system. The moving average form of the matrix, which is also the impulse response coefficient matrix, is structured as follows.

$$F_t = C_f + \alpha_0\varepsilon_t' + \alpha_1\varepsilon_{t-1}' + \cdots + \alpha_n\varepsilon_{t-n}' + \cdots \tag{3}$$

Here $F_t = [f_{1t} \quad f_{2t}]'$, C_f is a constant term and $\alpha_n = [\alpha_{ij,n}]$ is a 2×2 matrix of coefficients. $\alpha_{\mathrm{sh},n}$ reflects the effect of $f_{h,t-n}$ on f_{ht} in period $t-n$.

3.2. DCC-GARCH Model

$$V_t = \begin{bmatrix} \sigma_{s,t} & \sigma_{sh,t} \\ \sigma_{sh,t} & \sigma_{h,t} \end{bmatrix} \tag{4}$$

$$\sigma_{s,t} = \omega_{s,t} + \theta_{s,t}\varepsilon_{s,t-1}^2 + \delta_{s,t}\sigma_{s,t-1} \tag{5}$$

$$\sigma_{h,t} = \omega_{h,t} + \theta_{h,t}\varepsilon_{h,t-1}^2 + \delta_{h,t}\sigma_{h,t-1} \tag{6}$$

$$\sigma_{sh,t} = \rho_{sh,t}\sqrt{\sigma_{s,t}}\sqrt{\sigma_{h,t}} \tag{7}$$

$$\rho_{sh,t} = q_{sh,t}/\sqrt{q_{s,t}q_{h,t}} \tag{8}$$

$$q_{sh,t} = \rho_{sh} + \gamma_1(q_{sh,t-1} - \rho_{sh}) + \gamma_2(\eta_{s,t-1}\eta_{h,t-1} - \rho_{sh}) \tag{9}$$

Here $\rho_{sh,t}$ denotes the correlation coefficient between two different returns, and $\eta_{s,t-1}$ and $\eta_{h,t-1}$ denote the perturbation terms after normalisation. $\gamma_1\gamma_2$ are the parameters of the DCC.

3.3. BEKK-GARCH Model

$$V_t = C_0'C_0 + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'V_{t-1}B$$

$$V_t = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}\begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}\begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix}\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}\begin{bmatrix} \sigma_{11,t-1} & \sigma_{12,t-1} \\ \sigma_{21,t-1} & \sigma_{22,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{10}$$

In equation (10) the impact of new information transmission from the first market (stock index market) to the second market (futures market) is measured by ${a_{12}}^2$. The corresponding degree of information transmission from the second market to the first market is measured by ${a_{21}}^2$. The impact of lagged fluctuations in the first market on the second market is measured by ${b_{12}}^2$, and the corresponding impact of lagged fluctuations in the second market on the first market is measured by ${b_{21}}^2$.

4. Empirical Results

4.1. Unit Root Test

VAR modelling was carried out with the assurance that the data were cointegrated. Tables 1 and 2 present the unit root test results for the index data for China and the US respectively. As can be seen from the tables, both the domestic data and the US data obey first-order single integer, so VAR modelling can be performed for first-order differences.

Table 1. Unit root test results for CSI300 data

	ADF Test stat	ADF Test critical values			Probab.value	result
		1%	5%	10%		
St	-2.381	-3.430	-2.860	-2.570	0.1471	Unstable
△St	-31.922	-3.430	-2.860	-2.570	0.0000	Stable
Ht	-1.666	-3.430	-2.860	-2.570	0.4487	Unstable
△Ht	-32.184	-3.430	-2.860	-2.570	0.0000	Stable

(where Δ represents making a difference).

Table 2. Unit root test results for S&P 500 data

	ADF Test stat	ADF Test critical values			Probab.value	result
		1%	5%	10%		
St	-0.684	-3.430	-2.860	-2.570	0.8508	Unstable
△St	-35.417	-3.430	-2.860	-2.570	0.0000	Stable
Ht	-0.714	-3.430	-2.860	-2.570	0.4487	Unstable
△Ht	-35.972	-3.430	-2.860	-2.570	0.0000	Stable

(where Δ represents making a difference).

4.2. ARCH-LM Testing

Table 3 presents ARCH-LM tests for one difference between stock index and stock index futures prices in the US and China, choosing 8th and 10th order lags for the selected data, respectively. The results show that both sets of data reject the absence of ARCH effect at the 1% level of significance. From the table we can see that both sets of data have a significant ARCH effect.

Table 3. Differential ARCH-LM tests for stock index and stock index futures prices

Variables	F-test stat.	Probab.Value of F-test stat
CSI300 index	5.51	0.000
CSI300 index futures	5.44	0.000
S&P500 index	2.33	0.000
S&P500 index futures	2.27	0.000

4.3. VAR Model Construction and Impulse Response Analysis

In the following section, VAR modelling is carried out separately for both Chinese data and US data. Figure 1 shows the stability of the VAR system for the CSI300 data S&P500 data. From the empirical results, there are 12 eigenroots for the CSI300 data and 16 eigenroots for the S&P500 data, and the eigenvalues are all distributed within the unit circle, identifying the stability of the VAR modelling. Compared to the domestic data, the points of the S&P 500 data results are closer to the unit circle, which implies that some shocks in foreign markets are more persistent.

ISSN: 1813-4890

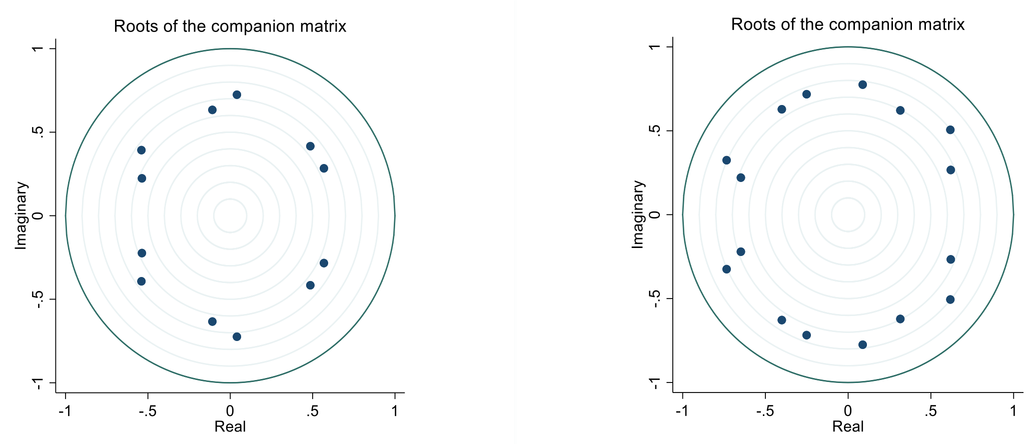

Figure 1. CSI300 data (left) S&P 500 data (right) VAR system stability discriminant plot

Figures 2, 3, 4 and 5 show the impulse response results between the CSI300 stock index and its stock index futures and between the S&P 500 stock index and its stock index futures respectively. The dashed lines show the confidence intervals and the solid lines show the impulse responses.

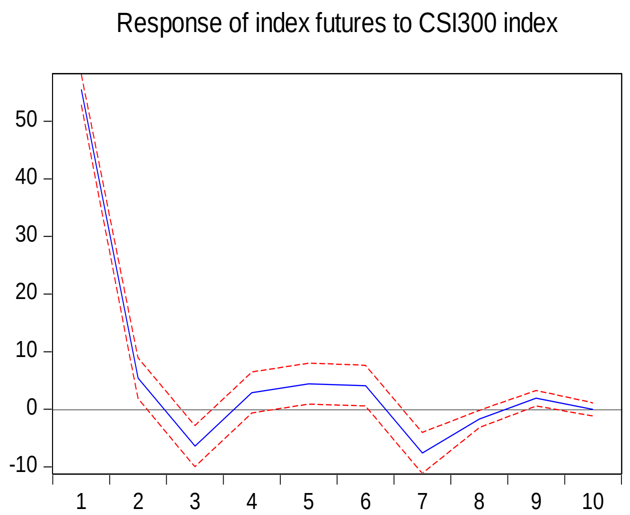

Figure 2. Response of index futures to CSI300 index

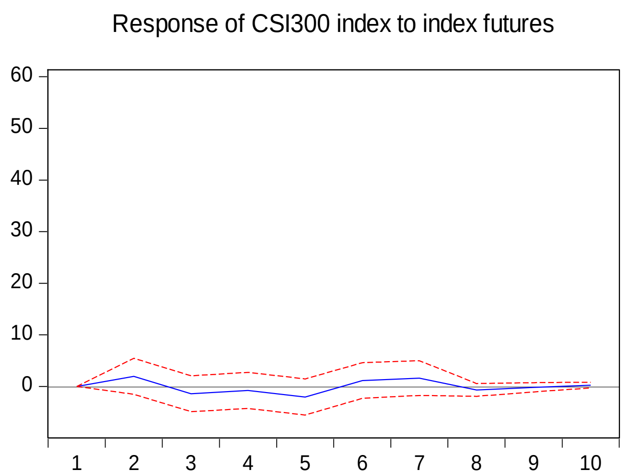

Figure 3. Response of CSI300 index to index futures

ISSN: 1813-4890

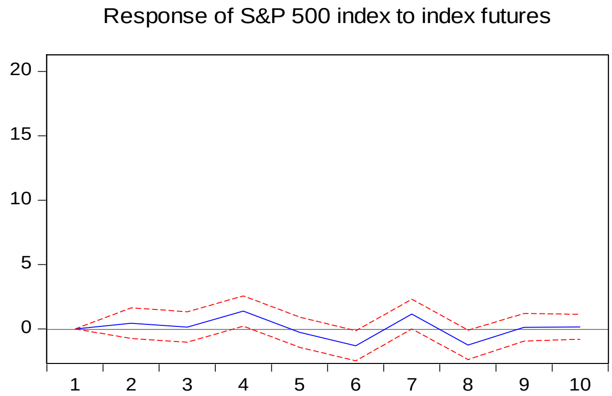

Figure 4. Response of index futures to CSI300 index

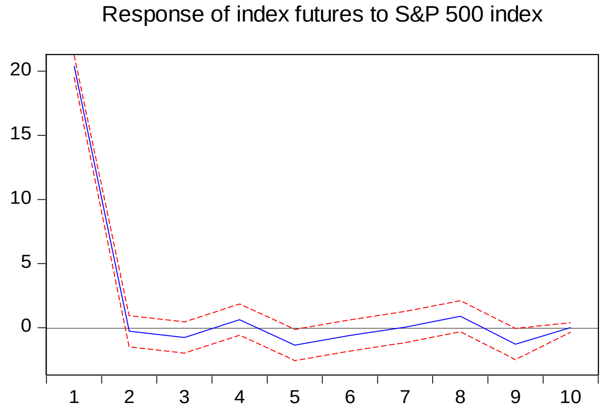

Figure 5. Response of CSI300 index to index futures

By analysing the impulse response charts, the similarity between the two markets is that only a one-sided impulse response relationship is evident between the equity indices and the corresponding futures markets. And both are shocks to the futures market from the stock index market. The futures market has essentially no impact on the stock index market. The impact of the equity index market on the futures market was strongest in the first two periods. The difference is that this shock is stronger in the domestic market, with the results in Figure 2 showing a positive shock of 50 percentage points in period 1, whereas looking at the foreign data results in Figure 5, the positive shock is only 20 percentage points in period 1. The results in Figures 2 and 4 show that there is a clear positive shock in periods 1-2, which tapers off in period 3, and the domestic data show a negative shock of 8 percentage points in periods 3 and 7 respectively. The foreign data in Figure 4 also show negative shocks in periods 3 and 5 and 6, but the intensity of the negative shocks is weaker. Therefore, the impulse responses lead to the following conclusion: there are only unilateral effects in both data sets, and the unilateral shocks are concentrated in the first two periods. There is a unidirectional link between volatilities.

4.4. Empirical Results of the DCC-GARCH and BEKK-GARCH Models

The model estimation results for VAR-DCC-GARCH are presented in Tables 4 and 5. Figure 6 and Figure 7 show the dynamic correlation coefficients of the two models respectively. VAR(6)-DCC-GARCH models 1 for CSI300 stock index and stock index futures and VAR(8)-DCC-GARCH model 2 for S&P 500 stock index and stock index futures were developed based on the FPE, AIC, HQ and IC criteria, respectively.

Table 4. Results of model 1 parameter estimation

	Estimates	z-Statistic
ω_s	11.039***	2.90
θ_s	0.071***	8.55
δ_s	0.930***	126.58
$\theta_s + \delta_s$	1.001	
ω_t	19.197***	3.25
θ_t	0.077***	9.09
δ_t	0.925***	124.42
$\theta_t + \delta_t$	0.997	
γ_1	0.018***	5.12
γ_2	0.977***	273.46
log	-10644	

Note: log is the log likelihood value of the model estimates, *** represents significant at the 1% statistical level.

Table 5. Results of model 2 parameter estimation

	Estimates	z-Statistic
ω_s	17.499***	5.05
θ_s	0.201***	9.34
δ_s	0.785***	36.80
$\theta_s + \delta_s$	0.986	
ω_t	17.611***	5.13
θ_t	0.229***	9.56
δ_t	0.767***	35.89
$\theta_t + \delta_t$	0.996	
γ_1	0.086***	5.34
γ_2	0.521***	8.04
log	-8096	

Note: log is the log likelihood value of the model estimates, *** represents significant at the 1% statistical level.

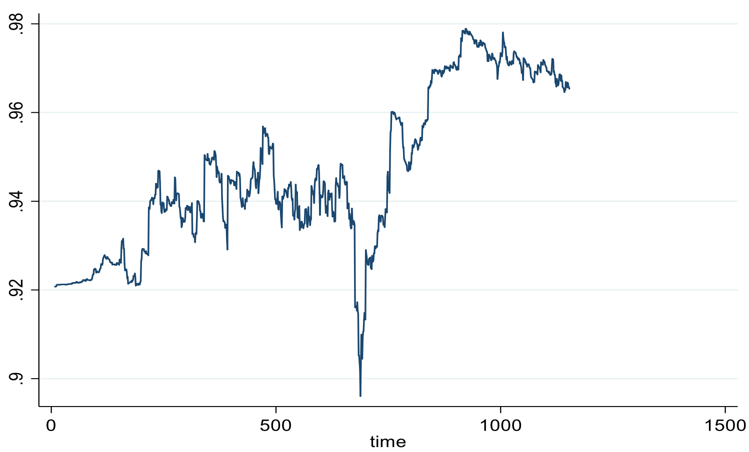

Figure 6. (Left VAR(6)-DCC-GARCH models 1 for CSI300 index)

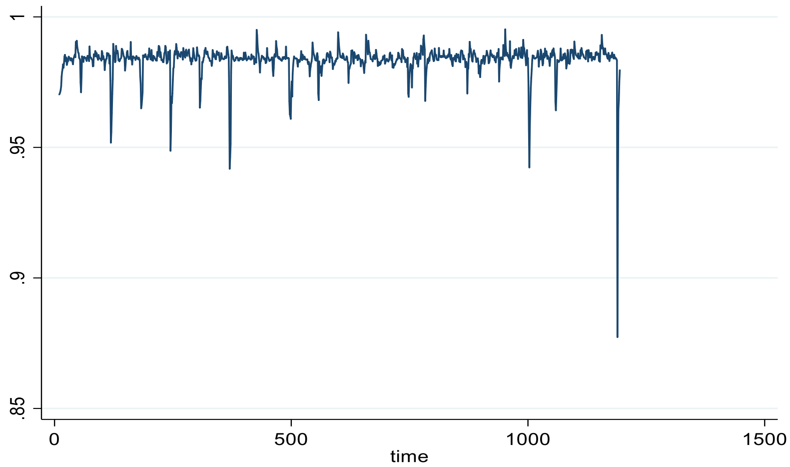

Figure 7. (Right VAR(8)-DCC-GARCH model 2 for S&P 500 index)

Tables 4 and 5 show the results of the model parameter estimates respectively, both of which are significant at the 1% level, which indicates that the DCC-GARCH model can pick up external information and that shocks from external information are somewhat persistent. The parameters θ in Model 1 are generally small, all below 0.1, which indicates that external volatility spillovers from lags in the domestic market have little impact on current market correlations. In Model 2, the parameter θ is generally above 0.2, indicating that external volatility spillovers from the lagged period in the US market have some impact on current market correlations. The parameter δ in the results of both models is generally larger both above 0.7. This indicates that the correlation coefficients between the spot and futures markets are more volatile, and that domestic markets are more volatile than foreign markets. The sum of the parameters θ and δ are both above 0.95, indicating a strong dynamic phase relationship between markets. And it is influenced by the lag period. This means that both data sets show a positive correlation. Secondly, model 1 fluctuates between 0.9 and 0.98, while model 2 maintains a dynamic correlation coefficient value between 0.95 and 0.1, with less fluctuation and a higher overall correlation. This suggests that there is a volatility spillover relationship between the stock index futures market and the spot market in both the US and China, and that this relationship is more stable and stronger in the US financial market, and that due to China's special economic system, there is volatility in the financial market that is susceptible to external information.

Table 6. Estimation results for Model 4 parameters

	Estimates	t-Statistic
a_{11}	0.264***	4.3079
a_{12}	0.027	0.3958
a_{21}	-0.021	-0.3888
a_{22}	0.225***	3.4749
b_{11}	0.969***	66.8836
b_{12}	0.001	0.0158
b_{21}	-0.001	-0.0778
b_{22}	0.965***	59.1319
$b_{11} \times b_{22}$	0.935	
log	-10691	

Note: log is the log likelihood value of the model estimates, *** represents significant at the 1% statistical level.

Table 7. Model V parameter estimation results

	Estimates	t-Statistic
a_{11}	-0.078	-0.7226
a_{12}	-0.654***	-5.5321
a_{21}	0.381***	3.3121
a_{22}	1.057***	8.4067
b_{11}	0.606***	7.9719
b_{12}	0.121***	2.7653
b_{21}	0.321***	4.3416
b_{22}	0.782***	18.0558
$b_{11} \times b_{22}$	0.473	
log	-8103	

Note: log is the log likelihood value of the model estimates, *** represents significant at the 1% statistical level.

Tables 6 and 7 present the results of the BEKK-GARCH model using the CSI300 data for the estimation of model four parameters and the S&P500 data for the estimation of model five parameters. By looking at the two tables below we can see that. The Model IV results show that most of them are insignificant, with the four coefficient estimates of a_12, a_21, b_12 and b_21 being insignificant. Based on the estimation results of the BEKK-GARCH model, it is clear that there is no significant volatility spillover relationship between the CSI 300 stock index futures contract and its stock index futures. This is mainly due to the poor transmission of price information between the stock index and its futures, which leads to the inability of the futures market to conduct timely and accurate price discovery. At the same time, the results estimated in Model 5 are in contrast to those in Model 4. There is a significant volatility spillover between the stock index market and the futures market, with a negative impact on the stock index market, reflected in the coefficient estimate of -0.654, and a positive impact on the stock index market, reflected in the coefficient estimate of 0.381. The lagged volatility spillover between the two markets is mainly positive, at 0.121 and The results of the BEKK-GARCH model estimation reflect that this volatility spillover effect is more pronounced in the US equity index and equity index futures markets. This reflects the fact that information flows are more fluid in the more developed US market with better market structure.

5. Conclusion

This paper focuses on the volatility spillover effect between stock indices and stock index futures. By comparing data from China and the US, we find that external information has a strong impact and persistence on both markets. The empirical analysis reveals that in the short term, there is a significant volatility spillover effect between the stock index and stock index futures markets in both the US and China, and that this effect shows a significant single lead effect. However, the correlation between stock index and stock index futures market data is not the same between the two countries, with the US market having a higher and more stable correlation and the Chinese market having a lower and more volatile correlation. The empirical analysis of the BEKK-GARCH model also shows that the volatility spillover effect between stock indices and index futures in emerging markets such as China is less pronounced than in developed markets, which is a deviation from previous research findings. At the same time, the stock index futures trading mechanism and related market rules are not yet perfect, and the functions of hedging and price discovery are not yet mature.

ISSN: 1813-4890

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