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Volatility Spillover Effects Between Chinese and International Stock Market - Based on the Asymmetric EGRACH Model

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Abstract: *This paper tests the volatility spillover effects between Chinese and international stock market from 2000 to 2019 by using asymmetric EGARCH model. Through the empirical analysis on the five indices' daily data, it is found that the volatility spillover effect of international stock market on Chinese stock market is not significant across the whole sample period. Ever since the opening of the Shanghai-Hong Kong Stock Connect and the Shenzhen-Hong Kong Stock Connect, however, the volatility spillover effect between Chinese and international market has been strengthened compared to the past. Based on the research conclusions, this paper puts forward some suggestions for the further development of Chinese capital market.*

Keywords: *Stock market, Volatility spillover effect, EGARCH model, Financial internationalization*

1. Introduction

With the continuous promotion of the tide of economic globalization over the past few decades, the connection of financial markets among countries is becoming much closer. Financial globalization has naturally become a trend affected by economic globalization. As a key element in economic activities, capital size has a strong positive correlation with the size of a country's financial market, which means the country obtains more international capital might have a more active stock market.

Financial market volatility has always been concerned by investors. In the context of financial globalization, the connection of financial markets among countries has been unprecedentedly strengthened. An important event occurred in a country might be known and digested by investors around the world in the least time. Taking the coronavirus pandemic in 2020 as an example, not only the economic activities around the world have been greatly impacted, but also most of the financial markets have seen dramatic fluctuations which rarely happen in history. For example, the Dow Jones Industrial index slipped over 36 percent in merely one month. Besides, the stock market triggered the circuit breaker mechanism repeatedly for the reason of sharp drop.

The transmission of volatility between financial markets mainly depends on the information transmission. The direction of information transmission between financial markets is characterized by spillover effect. For China, due to immature concept of investment and imperfect market system, the domestic stock market volatility was relatively high and unstable in the past, and the information transmission mechanism with the international market was not smooth enough. Nowadays, with the reform and opening up steppes into a new stage, the gradual opening of the financial market will be a crucial topic to be placed at an important position. Along with the opening of the Shanghai-Hong Kong Stock Connect in November 2014 and the Shenzhen-Hong Kong Stock Connect in December 2016, over one trillion yuan of foreign capital have flown into the Chinese stock market. Under this background, whether the volatility spillover effects between Chinese stock market and the international stock market have experienced structural changes compared to past years has become a subject worthy searching. It is necessary to get to understand the fluctuation features of different financial markets from the perspective of short term as well.

Many kinds of empirical model are implemented to study the spillover effects between financial markets. Huang and Ge (2015) find that the stock market, the bond market and the foreign exchange market all have asymmetric synergistic volatility spillover effects on the securities investment fund market in China using EGARCH-M model, among which the effect from stock market is the most significant. Urom et al. (2020) use EGARCH and other models to measure the asymmetric effect of

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crude oil prices on stock returns in several major oil producers, and discover that the effect of crude oil price on stock return is different in many aspects. Crude oil price has greater impact on stock return during the recession period than expansion, especially for Venezuela and Saudi Arabia. Multivariate GARCH models are also widely used in the research of spillover effect in financial market. Under the structure of BEKK-GARCH model, He and Hu (2011) find that there has been a bidirectional information transmission between Chinese mainland and Hong Kong and Taiwan. Liu and Zhou (2018) use the same model and conclude that the stock market in Chinese mainland can still not affect the volatility in developed stock markets, but is closely related to emerging stock markets such as Russia and India.

Besides GARCH models, VAR models are introduced to test the spillover effect between financial markets as well. White et al. (2015) introduced a multivariate VAR model to measure the spillover effect between market indices and the VaR of financial institutions, and find that the financial institutions in Asia are less sensitive to systemic shocks, but insurance companies are more sensitive to global shocks. Yip et al. (2020) use the four-dimensional FIVAR model to measure the spillover effect of implied volatility between crude oil and agricultural commodities after the financial crisis in 2008. They find that when crude oil has low volatility, the spillover effect of crude oil on all agricultural commodities will decrease, and contrariwise, the higher volatility of crude oil means higher volatility spillover effect on agricultural commodities.

The research on spillover effect is multi-dimensional, within which the spillover of volatility is relatively hot. From the perspective of research subjects, the heterogeneity of assets also leads to the differences of spillover effects among assets. This paper selects the stock markets in Hong Kong, the United States and Europe as the representatives of the international stock market, along with the Shanghai and Shenzhen stock markets in domestic, to analyzes the significance of the volatility spillover effect among markets, and to understand the transmission degree and path of the short-term volatility risk for domestic market. Then the paper would compare the differences between Chinese and international stock market under the circumstance of facing potential uprising risks in the short term, to help investors make some short-term predictions when dealing with the potential external shock. Besides, the conclusions in this paper can help to put forward some constructive suggestions to promote the long-term sustainable development of the market.

2. Methodology

The study mainly based on the the characteristics of financial market and the volatility spillover theory. In principle, leptokurtosis and heavy tail, fluctuation clustering and leverage effect are three features of volatility in financial market. For financial market, the spillover effect refers to the process in which a variable of a financial market asset affects variables of other financial market assets. The impact can be from the current period to the current period or from the previous n periods to the current period (n = 1, 2, 3, ...). Generally speaking, the spillover effects in financial markets include mean spillover and volatility spillover. This paper places emphasis on the volatility spillover effect of the stock market.

For the spillover effect, volatility spillover is what investors pay more attention to, for its strong relationship with the risk of asset return. The strength of volatility spillover effect between stock markets tested in this paper reflects the smoothness of information transmission between markets to some degree. The market is always in the process of dynamic change, therefore its significance affected by the spillover effects from other markets can not be unchanged as well. This paper would attempt to describe the dynamic change of spillover effect over time.

The heteroscedasticity model which can effectively describe the characteristics of financial time series is first proposed by Engle (1981) when studying the inflation rate series of British. He finds that the inflation rate series of British shows a significant ARCH effect, and puts forward the ARCH model. Then Bollerslev (1986) breaks the assumption of constant variance in traditional model and proposes the generalized autoregressive conditional heteroscedasticity (GARCH) model, which is expressed as follows:

$$y_t = \boldsymbol{\rho} \boldsymbol{x_t} + \mu_t \tag{1}$$

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} \tag{2}$$

Formula (1) is the mean equation, $\boldsymbol{\rho}$ and $\boldsymbol{x_t}$ are the coefficient vector and explanatory variable

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vector respectively, and μ_t is the residual term. Formula (2) is the conditional variance equation, where h_t is the conditional variance, $\alpha_0, \alpha_i, \beta_j$ are parameters to be estimated, and meet $\alpha_0 > 0$, $\alpha_i \geq 0$, $\beta_j \geq 0$. Parameter p is the order of GARCH term and q is the order of ARCH term.

Later Nelson (1991) constructed the exponential GARCH (EGARCH) model, to better model the conditional variance of asset return. The conditional variance equation is displayed as follows:

$$\ln h_t = \omega + \sum_{i=1}^{q} \beta_i \ln h_{t-i} + \sum_{i=1}^{q} \alpha_i \left| \frac{\varepsilon_{t-i}}{\sqrt{h_{t-i}}} - E\left(\frac{\varepsilon_{t-i}}{\sqrt{h_{t-i}}}\right) \right| + \sum_{k=1}^{r} \lambda_k \frac{\varepsilon_{t-k}}{\sqrt{h_{t-k}}} \quad (3)$$

For the estimation of volatility spillover effect across markets, this paper applies the EGARCH model added a variance term as follows:

$$\ln h_{At} = \alpha + \omega \ln h_{At-1} + \beta \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{At-1}}} - \sqrt{\frac{2}{\pi}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{At-1}}} + \delta X_{Bt-1} \quad (4)$$

Where parameter γ represents the degree of volatility asymmetry. When the financial time series has a characteristics of leverage effect, γ is usually negative, which means that the impact of negative shocks are stronger than positive shocks. X_{Bt} is the conditional variance of market B, which can despict its volatility intensity. The model can represent the spillover effect of market B on market A.

3. Data

The paper selects SSE Composite Index and SZSE Component Index as the representative indices of Chinese domestic stock market, and Hang Seng Index, S&P 500 Index and the Euro Stoxx 50 index as the representative indices of Hong Kong, the United States and Europe respectively. The sample period is set as all valid trading days between 2000 and 2019. In terms of variable representation, CPSZ, CPSC, CPHS, CPSP and CPST are used to represent the daily closing points of the five indices.

To make the sample data series smoother for further analysis, this paper makes logarithmic processing of the index return series using the formula as follows:

$$R_{it} = ln \frac{P_{it}}{P_{it-1}}, i = 1,2,\dots,5 \quad (5)$$

where P_{it} and P_{it-1} are the closing points of index i in period t and period t-1 respectively, and R_{it} is the logarithmic return of index i in period t. Parameter i is set to be from 1 to 5, representing stock market indexed from Shanghai, Shenzhen, Hong Kong, the US and Europe respectively.

Based on the data of five indices, we can obtain their time series diagrams and basic statistical characteristics (Table 1). It can be observed that all the indices exhibit a feature of fluctuation cluster, and high volatility in a specific period of time like 2008. From the perspective of horizontal comparison, the extreme value of the international stock indices is higher than the domestic indices when the volatility is high but lower when volatility is low.

Standard deviation can be viewed as a manifestation of volatility. According to the standard deviation of indices, the volatility of Shenzhen stock market is higher than Shanghai, and Hong Kong is higher than Europe, than the US. Besides, the returns of the five indices are negatively biased, indicating that the return distribution of the stock indices are asymmetric and are more prone to negative extreme values. The degree of negative bias of the two domestic indices is relatively more significant. It can be confirmed that the return series of each stock index show a leptokurtosis-and heavy-tail shape which is significantly different from the normal distribution as show in Table 1.

Table 1: Basic statistical characteristics of each stock index return series

	RCPSZ	RCPSC	RCPHS	RCPSP	RCPST
Sample size	4845	4845	4931	5029	5125
Mean	0.000160	0.000226	0.000098	0.000159	-0.000050
Middle	0.000630	0.000407	0.000498	0.000545	0.000205
Maximum	0.094008	0.095299	0.134068	0.109572	0.104376
Minimum	-0.092562	-0.097500	-0.135820	-0.094695	-0.090110
Std.deviation	0.015595	0.017601	0.014560	0.011899	0.014266
Skewness	-0.350430	-0.324997	-0.103476	-0.229335	-0.061305
Kurtosis	7.924199	6.575534	11.09936	11.64210	7.912257

ISSN 2706-655X Vol.4, Issue 4: 14-20, DOI: 10.25236/IJFET.2022.040403

4. Empirical Results

4.1. Stationarity Test

The paper firstly tests the stationarity of the sample series to avoid the problem of spurious regression. The following results are based on the standards with intercept and trend term, as show in Table 2.

Table 2: The results of stationarity test

Index	Variable	ADF test statistics	P-value	Stationarity
SSE Composite Index	RCPSZ	-68.15475	0.0001	Stationary
SZSE Component Index	RCPSC	-66.45052	0.0001	Stationary
Hang Seng Index	RCPHS	-70.47018	0.0001	Stationary
S&P 500 Index	RCPSP	-55.10140	0.0001	Stationary
Euro Stoxx 50 index	RCPST	-35.22924	0.0000	Stationary

According to results, as the difference of the original closing point series, all the ADF statistics of the return series are significant at a significance level of 1%, so all the series are stationary.

4.2. ARCH Effect Test

ARCH effect test is necessary before modeling a GARCH model to ensure that the time series are satisfied with heteroscedasticity. In this paper we use ARCH-LM test. Based on the results, it is believed that all the statistics are significant, which means the null hypothesis can be rejected, there is ARCH effect in the residuals of regression equation, as show in Table 3.

Table 3: The results of ARCH effect test

Variable	RCPSZ	RCPSC	RCPHS	RCPSP	RCPST
F-statistics	130.7897 (0.0000)	109.6476 (0.0000)	713.7976 (0.0000)	236.4777 (0.0000)	226.3418 (0.0000)
$N \times R^2$statistics	127.4024 (0.0000)	107.2639 (0.0000)	623.7413 (0.0000)	225.9411 (0.0000)	216.8477 (0.0000)

4.3. Volatility Spillover Effect Test (An Overall View)

Firstly, the study tests the whole sample period from an overall view. The test of volatility spillover effect is based on the coefficient δ in formula (4). δ represents the volatility spillover effect of stock indice B on stock indice A. Because a test involves multiple markets, considering the factors of different holidays in different regions, the non-overlapping trading data between two markets are eliminated. Then the paper achieves the estimated results of the spillover effect coefficient δ. The results of volatility spillover effect of domestic markets on international markets are presented in Table 4, while the results of volatility spillover effect of international markets on domestic markets are presented in Table 5.

Table 4: Volatility spillover effect of domestic stock market on international market

			Index B	
			RCPSZ	RCPSC
Index A	RCPHS	Parameter δ	20.69441^{***}	18.48072^{***}
		P-value	0.0011	0.0012
	RCPSP	Parameter δ	36.38065^{***}	27.72463^{***}
		P-value	0.0000	0.0000
	RCPST	Parameter δ	11.34172^{**}	10.04222^{**}
		P-value	0.0410	0.0375

Note: ***, **, * mean significant at the significance level of 1%, 5% and 10%, respectively.

According to the estimated results, the volatility spillover effect of domestic stock market on international stock market is stronger than that of international market on domestic market. Specifically, both Shanghai and Shenzhen markets show significant volatility spillover effect on Hong Kong and the

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US market at the significance level of 1%, and significant volatility spillover effect on Europe market at the significance level of 5%.

Table 5: Volatility spillover effect of international stock market on domestic market

			Index B		
			RCPHS	RCPSP	RCPST
Index A	RCPSZ	Parameter δ	-1.585760	-11.64782	-7.653305
		P-value	0.8010	0.1374	0.2580
	RCPSC	Parameter δ	-4.242934	-1.204671***	-3.710590
		P-value	0.5243	0.0061	0.5237

From another perspective, the volatility spillover effect of international market on domestic market is weak relatively, only S&P 500 Index shows significant volatility spillover effect on Shenzhen Component Index at the significance level of 1%. Therefore, based on the data from the first two decades of this century, our domestic stock market is more likely to have volatility spillover effect on international stock market, but less likely to be affected by the volatility spillover effect of international market.

4.4. Volatility Spillover Effect Test (A Recent View)

Based on the results above, the volatility spillover effect between domestic and international market shows differentiation to some degree. However, due to the opening of domestic financial market gradually, much more international investors have participated in doemstic stock market. A real milestone for the opening of stock market can be considered to be the launch of Shanghai-Hong Kong Stock Connect in 2014 and the Shenzhen-Hong Kong Stock Connect in 2016. The launch of connections means that international capital obtains a more direct and flexible channel to participate in the investment in Chinese market. For this reason, the paper sets the opening time of Shanghai-Hong Kong Stock Connect and Shenzhen-Hong Kong Stock Connect as the comparison time, to test the volatility spillover effect before and after opening of connections.

In the selection of specific time points, since the Shanghai-Hong Kong Stock Connect started on November 17, 2014, the paper sets 2015 as the node to divide the whole sample period; the Shenzhen-Hong Kong Stock Connect started on December 5, 2016, so the paper sets 2017 as the node to divide the whole sample period. Using the same model above, the relative results are presented in Table 6 and Table 7.

Table 6: Volatility spillover effect of domestic stock market on international market with comparison

			Index B			
			RCPSZ		RCPSC	
			Before 2015	After 2015	Before 2017	After 2017
Index A	RCPHS	Parameter δ	1.045028***	2.082223***	0.785538***	1.419019***
		P-value	0.0026	0.0023	0.0028	0.0035
	RCPSP	Parameter δ	13.96597***	1.993245**	0.933925***	23.58612**
		P-value	0.0000	0.0351	0.0000	0.0352
	RCPST	Parameter δ	0.270669	2.580462***	0.342487*	7.963724***
		P-value	0.2483	0.0011	0.0974	0.0082

Table 7: Volatility spillover effect of international stock market on domestic market with comparison

				Index B		
				RCPHS	RCPSP	RCPST
Index A	RCPSZ	Before 2015	Parameter δ	0.034562	-0.326431	-0.378238
			P-value	0.9062	0.2582	0.1527
		After 2015	Parameter δ	-3.121278***	-3.219454***	-1.115082*
			P-value	0.0064	0.0004	0.0834
	RCPSC	Before 2017	Parameter δ	-0.188823	-9.991610	-0.247704
			P-value	0.4869	0.1733	0.2595
		After 2017	Parameter δ	16.30280	23.58612	-8.922743***
			P-value	0.5411	0.2352	0.0008

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In Table 6, it is found that the parameter δ in the model of Shanghai and Shenzhen market on Hong Kong, the US and Europe are all significant after the opening of the Shanghai-Hong Kong Stock Connect and Shenzhen-Hong Kong Stock Connect, indicating that the volatility spillover effects are also significant. Before the opening of connections, the spillover effect of China on Europe is relatively weaker, with P-values of 0.2483 (Shanghai to Europe) and 0.0974 (Shenzhen to Europe), respectively. It is believed that the opening of Shanghai-Hong Kong Stock Connect and Shenzhen-Hong Kong Stock Connect have strengthened the volatility spillover effect of domestic market on European market.

According to the results in Table 7, it can be found that for Shanghai stock market, the spillover effects from the international stock markets are significantly strengthened, with the P-values drop from 0.9062 (Hong Kong to Shanghai), 0.2582 (the US to Shanghai) and 0.1527 (Europe to Shanghai) to 0.0064, 0.0004 and 0.0834, respectively. The last one is significant at 10%. For Shenzhen stock market, only the spillover effect from European market has significantly improved since the opening of connection, with the P-value drops from 0.2595 to 0.0008, while the volatility spillover effects from Hong Kong and the US market are still not significant enough at 10%.

In general, the opening of the Shanghai-Hong Kong Stock Connect has effectively improved the volatility spillover effect of international stock markets on Shanghai market, and effectively improved the volatility spillover effect of Shanghai on European market as well. For Shenzhen market, the largest change brought by the opening of Shenzhen-Hong Kong Stock Connect is to strengthen the bidirectional volatility spillover effect between Shenzhen and European markets, while the volatility spillover effects from Hong Kong and the US are still not significant. Based on the empirical results above, it can be confirmed that the relationship between domestic and international market in recent years has been closer compared to the past.

5. Conclusions and Policy Implications

5.1. Conclusions and Analysis

This paper selects five stock indices in domestic and abroad from 2000 to 2019 and bulids asymmetric EGARCH model to test the volatility spillover effects between markets. The study obtains the following conclusions:

Firstly, both domestic and the international stock market show fluctuation clustering, and the volatility is stronger in domestic. However, the extreme value of volatility in the international stock market is higher, which may be related to price limit mechanism in China.

Secondly, from the perspective of the whole sample period, domestic stock market has volatility spillover effect on international market to some degree, but is nearly not affected by the volatility spillover effect of the international market, which may also in line with the characteristics of domestic capital market. For a long time, due to the imperfection of capital market system and the restriction for investment channels, the foreign capital in China is limited, which indirectly leads to the difficulty of rapid transmission of peripheral market fluctuations caused by information shock. In some ways, this situation may keep domestic markets away from the negative shocks abroad, but it is not useful to be disconnected from the international market under the background of financial internationalization.

Thirdly, from a recent perspective, with the accelerated opening of domestic capital market, some features of internationalization have begun to appear in stock market. The opening of Shanghai-Hong Kong Stock Connect and Shenzhen-Hong Kong Stock Connect have made foreign investors another way to participate in Chinese stock market directly except QFII (Qualified Foreign Institutional Investor). It is observed that the volatility spillover effects between domestic and international market have been strengthened ever since the opening of connections. The connection between domestic and international markets is bound to be stronger in the future, which is of great benefit for the long-term construction of domestic capital market.

5.2. Policy Implications

Based on the research conclusions, the paper put forwards some suggestions focusing on the sustainable development of domestic financial market.

Strengthen supervision of domestic capital market. The domestic capital market is still in a relatively immature stage at present. The continuous opening of capital market is propitious to

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stimulate market vitality, but also poses new challenges to supervision at the same time. Now the revised Securities Law has been promulgated and implemented, then the main contradiction in the capital market has transformed to the implementation level. A mature capital market is inseparable from a fully-fledged legal system and strong implementation.

Strictly control the risks in the domestic capital market and monitor the potential systemic risks in financial market closely. Nowadays, the bidirectional volatility spillover effects between domestic and international markets have been observed. Although in the long run, it is the economy that decides a country's capital market, it does not mean that short-term risks can be ignored, especially when the short-term risk in international financial market rises, it is necessary to prevent and hedge the relative risk in time.

Deepen financial cooperation among countries and jointly maintain a stable global financial order. Economic globalization accelerates financial globalization, and the spillover between markets will be more significant. To bulid a stable global financial market system is not only useful to investors, but also helpful to promote the economic production and technological progress.

For investors, it is urgent to improve personal investment philosophy and risk awareness. With the prevalence of value investment concept, the ecological environment of Chinese stock market has been changed unconsciously. The immature investment behavior of blindly following the trend is bound to obtain less return. Therefore, individual investors should optimize their investment philosophy, make rational investment judgments and strengthen risk awareness and should not chase absolute return and ignore risks.

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