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Analysis on the Leverage Effect of Stock Market in China and America Based on EARCH Model

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Abstract: Volatility in the stock market as a significant standard is always used in the risk assessment field. Among them, asymmetry is the main feature of stock market volatility, and the leverage effect is one of the important mechanisms of asymmetry. It is of positive practical significance to study the leverage effect of stock market volatility in the open economy. In order to make volatility research more quantitative, economists proposed the ARCH model and continuously modified and innovated it, which expanded to the ARCH family model. This essay selected the 10 years of data (from 2012 to 2022) of the Shanghai Composite Index and the S&P500 Index that represent China's stock market and the American stock market, respectively, based on the EGARCH model, one of the ARCH family models, to analyze their volatility and by using Eview12.0 to build the EGARCH model to assess the leverage effect for both markets and compare the two market differences. As a result, it illustrates that both markets have significant leverage effects and the investors in two markets have obvious "herd behavior". Based on this empirical conclusion, the paper finally puts forward the corresponding policy suggestions for the government and stock investors.

Keywords: volatility, leverage effect, Shanghai Composite Index, S&P500, EGARCH model, herd behavior

1. Introduction

In the financial market, the financial risk is always triggered by the volatility of the stock price. The price of the stock reflects the demand and supply relationship in the stock market, and the volatility of the price also reflects the level of the price change. The volatility of security markets must be researched for asset portfolio and asset pricing purposes. In the past, the volatility of the price was used to adopt the standard deviation or GARCH model to have quantitative analysis. However, these methods cannot precisely describe the heteroscedasticity of the time series and ignore the leverage effect phenomenon in the stock market. The leverage effect of stock market volatility can be briefly explained by the asymmetric effect: when the stock price is high, the volatility would be low, and when the price is low, the volatility could be high. Therefore, in order to characterize the asymmetric effect in the security market, Nelson (1991) proposed the EGARCH model, which can more accurately describe the volatility of the stock price in the security market. Furthermore, investors' reactions to "positive" and "negative" news have a significant impact on investment portfolio and asset pricing, which can cause the leverage effect of stock market volatility indirectly. These reactions could indicate the level of maturity in the stock market and how rational the investors are as well. So

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far, the majority of the research focuses on using the ARCH category model to do empirical research on the volatility of the Shanghai Index, Shanghai 50 Index, and Hang Seng Index, but rarely research on the leverage effect in the Chinese stock market. This paper will, on the basis of previous research and using the EARCH model, mainly focus on the leverage effect in the Chinese stock market and compare relevant data with the American stock market's. From the research, it can test the leverage effect of both China's and American stock markets, and based on the coefficient of the EGARCH model, we can analyze the investor behavior in two markets so that it can give some suggestions for the government finance institutes and investors.

2. Overview of ARCH Type Model

Engle proposed the autoregressive conditional heteroscedastic model (ARCH) to characterize some possible correlation in the conditional variance of the prediction error, which has a significant contribution in predicting the change of a financial time series. The GARCH model is one of the ARCH family models that can model the time series with heteroscedasticity. The general GARCH model can be represented as below:

$$y_t = x_t\beta + \varepsilon \tag{1}$$

$$\varepsilon_t = \sqrt{ht} \cdot v_t \tag{2}$$

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha i\, \varepsilon^2_{t-1} + \sum_{j=t}^{p} \theta\, j h_{t-j} \tag{3}$$

The series is named the GARCH (p , q) process, and because the GARCH is the expanded expression of the ARCH model, it still has the same characteristics as the ARCH model. However, the conditional variance of the GARCH model is not only a linear function of the square of the lag residual but also a linear function of the lag conditional variance. The GARCH model is suitable for describing the high-order ARCH process conveniently when the computation is small, so it has greater applicability.

On the other hand, the GARCH model still has some defects in asset pricing. Firstly, the GARCH cannot explain the leverage effect in the stock market, which means the negative correlation between stock returns and return variability [1]. The prerequisite of the GARCH model is that it is assumed that the conditional variance will be a function of the square of the lag residuals. Therefore, the sign of the residual does not affect the volatility, which means the conditional variance responds symmetrically to positive and negative changes. However, numerous studies have shown that when negative information appears in the stock market, the expected return decreases and volatility increases, and the GRAH model cannot account for this asymmetrical phenomenon. Secondly, in order to guarantee the ht to be positive, the expression makes all the coefficients larger than zero [2]. Hence, the GARCH model implies that any increase in the lag term of ε^2_twill increase the h_t, thus precluding the stochastic volatility behavior of h_t, which makes the oscillation phenomenon possible when estimating the GARCH model.

Aiming at the deficiency of the GARCH model, researchers have proposed many improvement schemes. One of the most popular schemes is the EGARCH model, which was first proposed by Nelson in 1991. The function of the model is to present the asymmetry of conditional variance h_t in response to positive and negative disturbances in the market. The model can be expressed as below:

$$\ln(h_t) = \alpha_0 + \sum_{j=1}^{p} \theta\, j \ln(h_{t-j}) + \sum_{i=1}^{q} \alpha\, i g(v_{t-I}) \tag{4}$$

$$g(v_t) = \varphi_t v_t + \left|\frac{\varepsilon t}{\sqrt{ht}}\right| - E\left|\frac{\varepsilon t}{\sqrt{ht}}\right| \tag{5}$$

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The conditional variance in the model is in the form of a natural logarithm, which means that the leverage effect is exponential. If $\varphi \neq 0$, indicates the information function is asymmetrical; if $\varphi < 0$, the leverage effect is significant. Hence, the EARCH model can well describe the asymmetry in the financial market because the h_t in logarithmic form, which has no constriction to the coefficient in the model. Therefore, the EGARCH model can remedy the deficiency of the GARCH model.

3. Empirical Analysis

The paper selected the Shanghai Composite Index as the representative stock market for research (source from the WIND database). The range of data was from January 1st, 2012, to August 5th, 2022, nearly 10 years of Shanghai Composite Index closing prices. And the paper assumed the index daily yield is $r_t = \ln(p_{ut}/p_{t-1})$, p_t is the closing price of the Shanghai Composite Index on the day t.

3.1. Descriptive Statistics Analysis

Table 1: Shanghai Composite Index return statistics analysis (2012.1.1-2022.8.5).

Observations	Mean	Maximum	Minimum	Std.Devn.	Skewness	Excess Kurtosis	Median
2574	0.00015428	0.056036	-0.088729	0.013243	-0.99820	7.0323	0.00057626

Table 2: S&P500 index return statistics analysis (2012.1.1-2022.8.5).

Observations	Mean	Maximum	Minimum	Std.Devn.	Skewness	Excess Kurtosis	Median
2665	0.0004418	0.089683	-0.12765	0.010676	-0.92181	18.342	0.00063574

From Table 1, it can be seen that the SSE average return is positive but close to 0, which indicates that in this 10 year period, despite the price fluctuating heavily sometimes, the stock market generally has brought a constant and stable return to investors. And according to the skewness of -0.9982 and the excess kurtosis of 7.0323, it can reject the stock return's normal distribution.

Additionally, Table 2 shows some descriptive statistics about the S&P500's return. It can be found that the S&P500's average return is higher than the SSE's, so investors may have more opportunities than China stock market investors. Besides, the standard deviation is larger than that of SSE's, which can indicate the general return is more stable than SSE. Also, according to the value of the skewness and the excess kurtosis, we can find the statistics are not normal distribution as well. It obviously fits the characteristics of "sharp peak and thick tail".

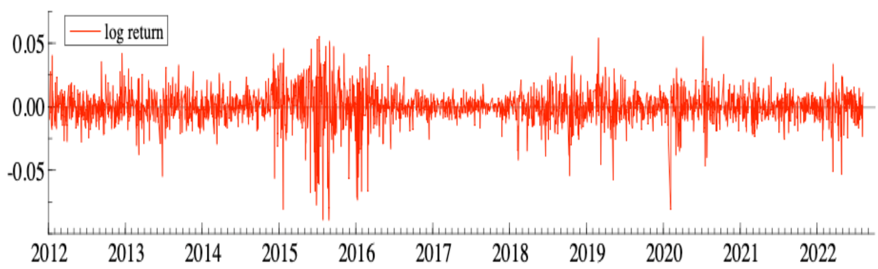

Figure 1: SSE.

Figure 2: S&P500.

Figure 1, the actual series of the log return plot, shows that the fluctuation of the return rate is small in one period of time but large in another, a phenomenon known in finance statistics as volatility clustering. The ARCH type model can have a good description of volatility clustering. Besides, from the graph, it can also be found that the Shanghai Composite Index may have a leverage effect. For example, during the 2015 period, China's stock market experienced a serious crash. Since the Shanghai Composite Index reached its peak on June 12, 2015, it has plummeted 32% to its bottom, wiping out more than 18 trillion RMB in share value, which was equivalent to about 30% of China's GDP in 2014 [2]. And from the graph, it can be found that the return fluctuated heavily from 2015 to 2016, which can indirectly prove the leverage effect phenomenon in the Chinese stock market.

We also have drawn the S&P500 log return series plot. Compared with the SSE index, we can find that the return on the S&P500 is more stable than that of the SSE from 2012 to 2020. However, in 2020, it has a heavy fluctuation, and after this, the S&P500's return becomes more fluctuated.

Because the financial data sometimes has lag and correlation situations, if we use the data analysis directly, it may result in "spurious regression" [3]. In order to avoid the spurious regression issue and have a better result, it should conduct an ADF test for the Shanghai Composite Index return to test whether the data has unit root. The results are as below:

Table 3: ADF test for the Shanghai Composite Index return.

D-lag	t-adf	Beta Y	sigma	AIC	F-prob	5%	1%
6	-19.05	0.03653	0.01317	-8.657	0.1221	-3.41	-3.97

Table 4: ADF test for the S&P500 Index return.

D-lag	t-adf	Beta Y	sigma	AIC	F-prob	5%	1%
7	-19.4	-0.15037	0.01036	-9.316	0.0000	-3.41	-3.97

According to table 3, the SSE's t-adf value is -19.05, which absolute value is larger than the 1% (-3.97), 5%(-3.41) critical values. Therefore, it should reject the unit root in the data. In other words, the Shanghai Composite Index return is stationary and will not experience the spurious regression issue. Therefore, the result can reflect actual problems well. And from table 4, the S&P500's t-adf value is -19.4, which is larger than the 1% and 5% critical values. Therefore, the S&P500's return is stationary as well.

3.2. Model Establishment

In this paper, we use the EGARCH model to analyze the leverage effect in the Chinese stock market and compare its results with those of the American stock market. The EGARCH (1,1) model form and the results are as follows:

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$$\ln(\sigma^2_t) = \varpi + \alpha[\frac{|\mu t-1|}{\sqrt{\sigma 2t-1}} - \sqrt{\frac{2}{\pi}}] + \gamma\frac{\mu t-1}{\sqrt{\sigma 2t-1}} + \beta\ln(\sigma^2_{t-1}) \quad (6)$$

Table 5: The results of EGARCH model coefficient in SSE Index.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	-0.257966	0.020092	-12.83924	0.0000
C(2)	0.189599	0.008870	21.37460	0.0000
C(3)	-0.016217	0.005258	-3.084141	0.0020
C(4)	0.986625	0.002228	442.9085	0.0000
R-squared	-0.000128	Mean dependent var		0.000150
Adjusted R-squared	0.000262	S.D. dependent var		0.013284
S.E. of regression	0.013282	Akaike info criterion		-6.130588
Sum squared resid	0.453198	Schwarz criterion		-6.121478
Log likelihood	7878.740	Hannan-Quinn criter.		-6.127285
Durbin-Watson stat	1.925114			

Table 6: The results of EGARCH model coefficient in S&P500 Index.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	-0.832615	0.063342	-13.14473	0.0000
C(2)	0.267390	0.016724	15.98849	0.0000
C(3)	-0.189153	0.011347	-16.67058	0.0000
C(4)	0.933505	0.005653	165.1475	0.0000
R-squared	-0.001712	Mean dependent var		0.000442
Adjusted R-squared	-0.001337	S.D. dependent var		0.010678
S.E. of regression	0.010685	Akaike info criterion		-6.804785
Sum squared resid	0.304278	Schwarz criterion		-6.795947
Log likelihood	9071.375	Hannan-Quinn criter.		-6.801587
Durbin-Watson stat	2.286984			

(Source from the Eviews12.0, C(1) represents the constant ϖ, C(2) represents the coefficient α, C(3) represents the coefficient of the asymmetric term γ, C(4) represents the coefficient β.)

4. Results Analysis

According to the result of the EGARCH model coefficient for both China and American stock markets, we can find that their asymmetric coefficients γ are negative, which can prove that both markets are influenced by the leverage effect. The China stock market's γ is -0.016217 and the American stock market's γ is -0.189153. Both have a negative value of γ, and even the American stock market's γ absolute value is larger than the value of the China stock market, which indicates the American stock market's leverage effect is more significant than that of the Chinese.

In addition, the leverage effect is also proved by the above coefficients. The impact of bad news on the stock closing index is greater than the impact of good news on the stock closing index. In the Shanghai Composite Index, if there is good news ($u_{t-1}>0$), the information shock has $\alpha + \gamma = 0.189599 + (-0.016217) = 0.173382$ times of the logarithm of the condition variance; if there is bad news ($u_{t-1}<0$), the information shock has $\alpha + \gamma\cdot(-1) = 0.189599 + (-0.016217)\cdot(-1) = 0.205816$ times of the

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logarithm of the condition variance. In the S&P 500, the good news generates 0.26739 + (-0.189153) = 0.078237 times the shock and the bad news generates 0.26739 + (-0.189153)·(-1) = 0.456543, that is, the fluctuation caused by the negative return rate shock is greater than the fluctuation caused by the peer positive shock [4].

From the perspective of investor behavior, both markets $\alpha>0$ reflect the fact that the stock volatility also presents clustering phenomenon that past volatility disturbances have a positive but slowing impact on future market volatility, larger fluctuations are often followed by larger fluctuations, and stock market investors are more speculative. Additionally, $\alpha + \beta > 0$, indicating the volatility is persistent and current information is significant for predicting the future conditional variance. According to the volatility in both markets and the leverage effect in two markets, we can find the Shanghai Composite Index and S&P500 Index investors may have "herd behavior" as well. "Herd behavior" has a side effect that may exacerbate volatility, destabilize markets, and increase the fragility of the financial system [5]. Investors in both the Shanghai Composite Index and the S&P500 use the same investment strategy: when the stock price is high, a large number of investors buy the stock; when the stock price falls, investors sell their stocks as quickly as they can. This behavior can be concluded to be "herd behavior", which can also be one of the reasons for the leverage effect in stock market. Based on the value of $\alpha + \beta$ for both markets, the SSE is 1.176224, S&P500 is 1.200895. The influence is enduring. When the market is hit by bad news, the investors' confidence may be difficult to rebuild in the short term. Because the S&P500's coefficient is larger than the Shanghai Composite Index's, this phenomenon in the S&P500 is more significant than in the SSE.

5. Policy Suggestion

The above empirical analysis shows that two stock markets have significant leverage effects. In order to make the stock market more mature and stable, the paper put forward two suggestions from the point of view of the government and investors.

(1) Due to the leverage effect, the effect of stock market asymmetry is to increase volatility of the stock, which may have negative impacts on the liquidity of the stock market and the open market established. Therefore, the financial institution should strengthen the disclosure of the stock information so that investors can form rational expectations when confronted with bad news. In this way, it can reduce the adverse fluctuations caused by the leverage effect. Hence, building a sound disclosure information system is necessary [6].

(2) Secondly, from the point of view of investors, it should always be rational to treat stock prices. If the prices are at a low level, investors should keep confidence in the market; otherwise, it may cause the "herd behavior" effect. A large amount of research shows that "herd behavior" can trigger the financial crisis and even produce a contagion effect [7]. Therefore, having a rational investment strategy for investors is crucial for the market's long-term development.

6. Conclusion

Based on the above analysis of the leverage effect for both markets, the following conclusion can be drawn:

(1) Based on the descriptive statistics analysis, it found that both distribution of the SSE and S&P500 stock market return is in shape of "sharp peak and thick tail".

(2) The coefficient of the EGARCH (1,1) Model reflects that the China stock market and the American stock market have the leverage effect. The American stock market's leverage effect is more significant than China's stock market.

(3) According to volatility clustering, it explains that the investors in two markets have "herd behavior", that is, adopting chasing high prices and dropping low prices strategies, which can increase the volatility of the market.

This paper still has some drawbacks in the process of research. Firstly, it only selected 10 years of share returns for both markets, which may not reflect the stock market's actual situation in the long term. In the future, the research will select more than 10 years of statistics to build the EARCH model so that we can find more precise results from the research. Secondly, there are still some objective factors that may affect the volatility. Among them, the COVID-19 is one of the most important factors. According to a large number of studies, the pandemic had an obvious impact on volatility during the COVID-19 period, and as volatility increased, the level of volatility became higher than usual, particularly in the Chinese and American stock markets [8]. Hence, in order to find out the leverage effect for both markets exactly, the essay will separately analyze the COVID-19 period situation and the pre-Covid time situation and, eventually, compare pandemic period volatility with pre-Covid time volatility.

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