

# The Analysis of the Volatility of China's Stock Market

## Taking Shanghai Composite Index as an Example

Qiqi Sun

School of Economics and Management  
Nanjing University of Science and Technology  
Nanjing, China

**Abstract**—This paper chooses the relatively persuasive stock index in China, Shanghai Composite Index (000001), using data from December 31, 1997 to April 4, 2018 as the sample of the paper and then calculate them according to the logarithmic rate of return. By using EVIEWS 7 software to test the effect of these samples, this paper select and establish the relevant model, and the fluctuation characteristics of return series are analyzed briefly. Due to the discovery of stock market returns has obvious ARCH effect and through repeated attempts, the author finds that GARCH (1, 1) model is more appropriate when describing the characteristics of the fluctuation of stock index compared with other similar models. Through the descriptive statistical test and the ADF unit root test, it is found that the fluctuation of equity market has the characteristics of "thick" and "clustering". The volatility of the stock returns has a "cluster" character and the financial time series is stable and has the conditional heteroscedasticity. Good news on the impact of the market and investment is weaker than bad news, investors and the market is more sensitive to the bad news. At the end of the empirical analysis, by drawing the information impact curve, we can intuitively see the traits of the financial time series, that is, leverage effect.

**Keywords**—log return rate; GARCH model family; asymmetry; lever age effect; information impact

### I. INTRODUCTION

China's stock market has only developed not more than 30 years, and it is an emerging market. It has unique fluctuation characteristics. As the impact of various types of volatility on China's securities market and domestic economy is very different, so we need to further analyze the Chinese stock market, through a large number of data samples to explore the features of the volatility of China's stock index. Compared with some papers, this paper uses more sufficient sample data to analyze the volatility characteristics of the stock market entirety.

Many scholars at home and abroad have used these models to study stock index yield series, and have made much progress in many aspects. Robert F. Engle (1982) proposed the characteristic of the time-varying variance of the financial time series with the aid of the autoregressive conditional heteroscedasticity model, and used the method of fitting the residual of the stock return sequence to describe

the "clustering" characteristics of the sequence fluctuation. Campbell and Hentschel (1992) think that relative to good news, the phenomenon of greater impact on volatility can be explained by the "leverage effect". According to the "leverage effect", the reduction of the current income reflected by the stock price will lead to the increase of the financial leverage and debt ratio of the enterprise, and the financial risk of the enterprise will increase, and also the fluctuation will be greater. Wang Haibo (2015) used Shanghai and Shenzhen 300 as his research objects, and also thought that the volatility of stock market returns had the behaviors of peak and thick tail and asymmetry. At the same time, he tested and compared  $p=1$  and  $q=1$ 's GARCH, EGARCH and TARCH models successively. Finally, it is considered that the GARCH model of  $p=1$  and  $q=1$  has poor ability to depict the volatility form of stock index return than EGARCH and TARCH models. Zhe Lin (2018) studied the econometric features of the SSE Composite Index, using GARCH type models. Results show that the SSE Composite Index possesses significant properties of time-varying and clustering. And its series distribution presents leptokurtosis with significant ARCH and GARCH effects.

### II. THE MODEL

#### A. GARCH Model

The advantage of the GARCH model is that it can use a relatively simple model instead of a high order ARCH model. The related literature confirms that the GARCH model is better in the study of the financial time series. Where  $p$  is the order of autoregressive GARCH,  $q$  corresponds to the ARCH order. When  $P$  and  $q$  are equal to 1, which is the most common, the variance equation of GARCH model can be expressed as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \quad (1)$$

Where,  $\alpha_0$  is the constant term,  $\alpha_1$ 、 $\beta_1$  are the coefficients,  $u_{t-1}^2$  represents volatility information obtained from the earlier stage.  $\sigma_{t-1}^2$  is predictive variance of the last phase.

It can be seen from the upper formula that the value of variance depends not only on the past value of the shock, but

also on its own past value. Similarly when both  $p$  and  $q$  are not equal to 1, the variance equation is:

$$u_t = \sqrt{\sigma_t} \cdot v_t \quad (2)$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^p \alpha_i u_{t-i}^2 + \sum_{j=1}^q \beta_j \sigma_{t-j}^2 \quad (3)$$

$v_t$  is white-noise process, and irrelevant to  $u_{t-1}$ . Each  $v_t$  is identically distributed, and subject to normal distribution.  $u_t$  is the square of the estimated residuals under the collection of all information in the past.  $\alpha_i, \beta_j \geq 0$  ( $i=1,2,\dots,p$ ;  $j=1,2,\dots,q$ ).

### B. TARCH Model

The TARCH model was brought forward by three scholars headed by Zakoian (1990), and an extension of the ARCH model. The model can explain and analyze the characteristics of fluctuation asymmetry. So the conditional variance expression is as follows:

$$\sigma_t^2 = \omega + \alpha u_{t-1}^2 + \gamma u_{t-1} d_{t-1} + \beta \sigma_{t-1}^2 \quad (4)$$

We use the indicative variable  $d_{t-1}$  to represent the conditional statement  $\text{RESIDE}(-1) < 0$ . If  $u_{t-1}$  is less than 0,  $d_{t-1}$  equals 1; otherwise it will be 0. If  $\gamma \neq 0$ , it means that different kinds of information will have different effects on conditional variance. At that time, when  $\gamma > 0$ , it indicates that its fluctuation was leveraged and its main role was to increase the range of fluctuation. Conversely, when  $\gamma < 0$ , the asymmetry effect would weaken the fluctuation. Good news, that is,  $u_t$  is greater than 0, there is a shock  $\alpha$  to it; Otherwise, the bad message,  $u_t$  is less than 0, there will be a shock  $\alpha + \beta$ .

### C. EGARCH Model

Since 1976, many researchers have found a negative correlation between stock price and future price fluctuation. Obviously, the standard GARCH model cannot capture this asymmetric effect. Using the GED (Generalized Error Distribution), we propose an exponential GARCH model,

that is, the EGARCH model, which can measure the leverage effect. The conditional variance is specified as:

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \alpha \left| \frac{u_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{u_{t-1}}{\sigma_{t-1}} \quad (5)$$

If leverage effect exists, it is necessary to pass the assumption that the leverage coefficient  $\gamma$  is not 0, which means that information is asymmetric. When the leverage coefficient  $\gamma$  is less than 0, it is shown that the negative fluctuations are bigger than the positive fluctuations. The good information and the bad information have a differential influence on the conditional variance. The good information causes a shock  $\alpha - |\gamma|$ , and the bad information will generate an impact  $\alpha + |\gamma|$ . If the leverage coefficient is greater than 0, it is opposite.

## III. EMPIRICAL ANALYSIS

### A. Data Selection and Processing

China's stock market imposed a price limit trading system since December 16, 1996, the fluctuation of data has been significantly reduced since then. In view of this, in order to reduce the impact of some outliers on the final results and improve the accuracy of the model, this paper selects the daily closing price of the Shanghai Composite Index (000001) from December 31, 1997 to April 4, 2018 as the data sample. The sample is processed by logarithm to reduce the error, and  $R = \ln p_t - \ln p_{t-1}$  will be used as the closing price of the Shanghai stock index.  $R$  is the log return rate of the stock index. Because of its smaller results, this paper magnifies the results by 100 times, thus getting 4907 data samples. Compared with SPSS, EVIEWS is more suitable for financial time series analysis, so EVIEWS 7 is used for further analysis.

### B. Test of Basic Statistic Characteristics of Return Series

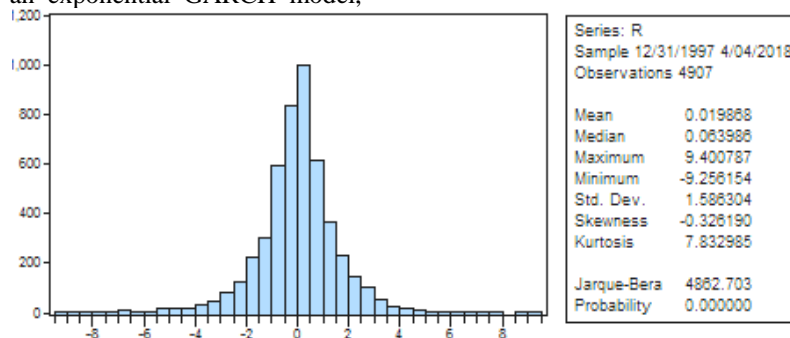


Fig. 1. Descriptive statistics of Shanghai composite index returns.

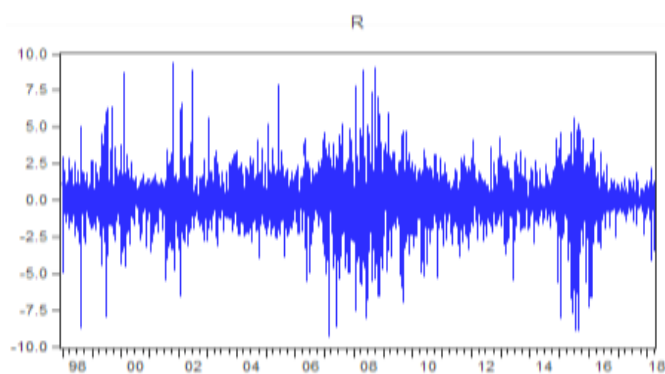


Fig. 2. Trend chart of yield volatility.

TABLE I. RESULTS OF DESCRIPTIVE STATISTICS

Average Value	Standard Deviation	Kurtosis	Skewness	J-B Statistics	P Value
0.0199	1.586	7.833	-0.326	4862.703	0.000

From "Fig. 1" and "Fig. 2", combined with "Table I", it can be seen that the average yield rate is 1.99%, but the standard deviation is 1.586. It indicates that the volatility is larger and the investment risk is higher. The skewness is  $-0.326 < 0$ , and the average value is on the left of the median, indicating that the distribution has a negative deviation, or a left offset. It is intuitively shown that the tail of the left is longer than that on the right side, demonstrating that the yield curve of the Shanghai composite index is biased and slightly left. The kurtosis value is 7.833, obviously, larger than 3, showing that the distribution is excessive kurtosis, not normal distribution. And the p value of J-B statistics is 0. This result can also verify the above conclusion, stating clearly that the sequence does not obey normal distribution. This shows that the fluctuation of the sequence has a nature of leptokurtosis and fat-tail of the left side. From "Fig. 2", we find that the daily returns of the Shanghai Stock Exchange index fluctuate more sharply in some time periods, and are more stable in other time periods, indicating the volatility clustering phenomenon.

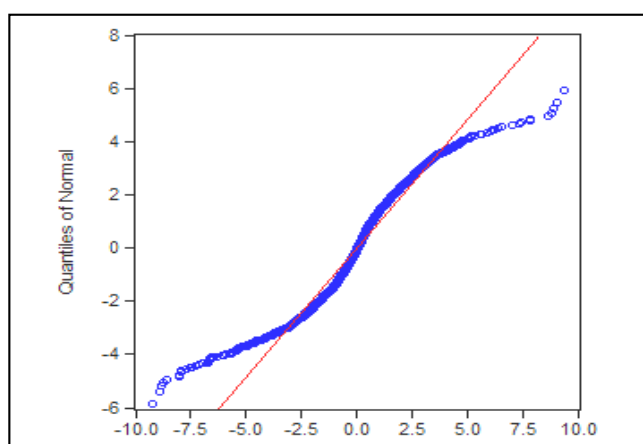


Fig. 3. QQ scatter plot.

From "Fig. 3", we can see that the lower end of the QQ scatter plot has a downward trend, while the upper end is upwards. The price distribution of the Shanghai composite index has a peak nature, and from "Fig. 3", we can see that only the middle part is similar to a straight line, and the upper end of the figure has a more obvious right deviation, indicating that it has a more obvious right deviation and possesses a thick tail.

### C. Stability Test of Return Series

First, we use ADF test to see whether the return series is stable, as shown in "Table II" and then we can determine whether we can use traditional estimation method to study the volatility of stock prices.

TABLE II. STATISTICAL TEST FOR STATIONARITY OF RETURN SERIES

Variable	ADF Test Value	Critical Value			P Value	Result
		1%	5%	10%		
R	-28.309	-3.960	-3.411	-3.127	0.000	Pass

From "Table II", we can see that the ADF value is  $-28.309$ . It is much smaller than the critical values  $-3.960$ ,  $-3.411$  and  $-3.127$  under 1%, 5% and 10% levels, and the accompanying p value is 0 that means significantly reject the null hypothesis of stability. Therefore, it is possible to determine that the return series is stationary.

### D. ARCH Effect Test of Return Series

The fluctuation has an obvious cluster phenomenon in "Fig. 4", which shows that the error terms may have conditional heteroscedasticity. As long as we prove that there is ARCH effect in one of the lagged terms, we may believe that the residual sequence of this autoregressive model has ARCH effect. The results of ARCH-LM test of heteroscedasticity are shown in TABLE III and IV, TABLE III selected lag order of 3 and TABLE IV selected lag order of 10 in order to conduct necessary comparison and analysis. It was found that the concomitant probability of statistics was still 0 after inspection, less than that of 5% critical level. Therefore, it can be concluded that the higher order of ARCH effect in the Shanghai composite index can be found, and the higher order ARCH effect can use the lower order GARCH model to fit it well.

TABLE III. ARCH-LM TEST RESULTS OF RESIDUAL SEQUENCES WITH LAG ORDER OF 3

Heteroskedasticity Test: ARCH			
F-statistic	116.5874	Prob. F(3,4899)	0.0000
Obs*R-squared	326.7215	Prob. Chi-Square(3)	0.0000

TABLE IV. ARCH-LM TEST RESULTS OF RESIDUAL SEQUENCES WITH LAG ORDER OF 10

Heteroskedasticity Test: ARCH

F-statistic	50.68633	Prob. F(10,4885)	0.0000
Obs*R-squared	460.2495	Prob. Chi-Square(10)	0.0000

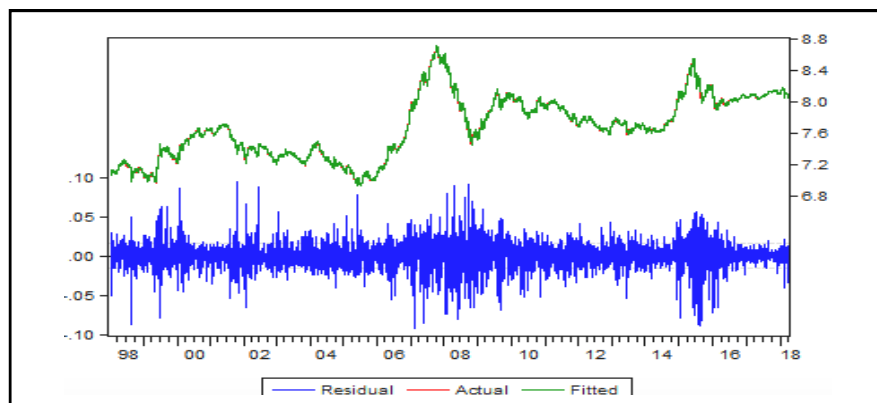


Fig. 4. Residual series diagram.

## E. Autocorrelation Test of Return Series

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
1		0.025	0.025	2.9493	0.086
2		-0.027	-0.028	6.5226	0.038
3		0.035	0.037	12.686	0.005
4		0.054	0.052	27.223	0.000
5		-0.002	-0.003	27.252	0.000
6		-0.053	-0.052	41.262	0.000
7		0.026	0.025	44.704	0.000
8		0.015	0.008	45.769	0.000
9		0.001	0.006	45.775	0.000
10		-0.008	-0.004	46.123	0.000
11		0.014	0.011	47.038	0.000
12		0.036	0.031	53.365	0.000
13		0.038	0.040	60.424	0.000
14		-0.023	-0.023	62.952	0.000
15		0.053	0.053	76.704	0.000
16		0.011	-0.000	77.264	0.000
17		0.003	0.004	77.295	0.000
18		0.023	0.025	79.821	0.000
19		-0.016	-0.020	81.013	0.000
20		0.022	0.019	83.448	0.000

Fig. 5. Autocorrelation test of logarithmic return rate.

The residual series diagram as in "Fig. 4" shows that the residuals fluctuate regularly, indicating that there may be autocorrelation. From Fig. 5, we can see that the P value is 0.086 when the lag order is 1, while the others are less than 0.05. It significantly rejects the null hypothesis. The stock return rates of Shanghai composite index are influenced by the rate of return of stock market the day before, which are not independent of each other. Chinese stock market still be a weak efficiency market. Many scholars have found this characteristic through empirical analysis. For example, Sentana E et al. (1992) studied the daily return rate of America stock index for nearly a century, drawing the conclusion: the return rate the day before can affect the autocorrelation sequence of the rate of return. Tang Yu, Ceng Yong, Tang Xiaowo (2002) also came to a conclusion that Shanghai stock return series has positive correlation; and Chen Rui (2004) is devoted to analysing the factors influencing stock return autocorrelation.

## F. Empirical Analysis of GARCH Model

Since the previous analysis has proved that the return series has the ARCH effect, and the higher order GARCH effect can be well fitted with the lower order GARCH model, and the GARCH model is more suitable to be used to describe some characteristics of the volatility of yield. And by reading references and learning from the scholars concerning the stock market, I found that most of the fluctuation of stock index has the characteristics of asymmetry, and hope that the further research can verify the conclusion.

TABLE V. AIC VALUE TEST RESULTS FOR THE GARCH MODEL FAMILIES

Model Form	AIC	Model Form	AIC	Model Form	AIC
GARCH	-5.745	TARCH	5.747	EGARCH	-5.758
(1, 1)		(1, 1)		(1, 1)	
GARCH	-5.744	TARCH	-5.746	EGARCH	-5.751
(1, 2)		(1, 2)		(1, 2)	
GARCH	-5.744	TARCH	-5.746	EGARCH	-5.751
(2, 1)		(2, 1)		(2, 1)	
GARCH	-5.744	TARCH	-5.746	EGARCH	-5.757
(2, 2)		(2, 2)		(2, 2)	

AIC considers the statistical goodness of fit of the model and the number of parameters used to fit it. The smaller the AIC value is, the better the model is. It shows that the model obtains sufficient fitting degree with fewer parameters. From "Table V", GARCH, TARCH and EGARCH model obtain the minimum AIC value in  $p=1$  and  $q=1$ , and pass the test of significance, so the model GARCH (1, 1), TARCH (1, 1)

and EGARCH (1, 1) is more suitable for the empirical study of Shanghai Composite index.

The equation of GARCH model is:

$$GARCH = C(2) + C(3) * RESID(-1)^2 + C(4) * GARCH(-1) \quad (6)$$

The estimated results of the obtained GARCH (1, 1) model are as follows:

The mean equation is:

$$P_t = 0.0049 + 0.9994P_{t-1}$$

$$Z = (1.5418) \quad (2420.730)$$

The variance equation is:

$$\sigma_t^2 = 1.70 \times 10^{-6} + 0.0804u_{t-1}^2 + 0.9168\sigma_{t-1}^2$$

$$Z = (7.0397) \quad (19.7028) \quad (246.0380)$$

The slope coefficients of the variance equation are statistically significant, and the ARCH-LM residuals of the GARCH (1, 1) model are tested, and the results are shown in "Fig. 6".

Heteroskedasticity Test: ARCH

F-statistic	0.272721	Prob. F(1,4903)	0.6015
Obs*R-squared	0.272818	Prob. Chi-Square(1)	0.6014

Fig. 6. ARCH-LM test results of residual series of GARCH (1, 1) model.

Then the results shown in "Fig. 6" indicates, p values of the F and  $T \times R^2$  statistic are 0.6015 and 0.6014, greater than 5% significance level, so the ARCH effect does not exist, and heteroscedasticity has been eliminated. Therefore, the GARCH model of  $p=q=1$  can better fit the return rate series.

TABLE VI. ESTIMATED RESULTS OF GARCH MODEL (1,1)

Model	$\alpha_0$	$\alpha_1$	$\beta$	AIC	SC
GARCH (1, 1)	$1.70 \times 10^{-6}$	0.080	0.917	-5.745	-5.738

We can see from "Table VI" that  $\alpha_1 + \beta = 0.997$ , so the sum of two coefficients is less than but close to 1, indicating that the impact of  $\sigma_t^2$  is persistent. The current information plays an important role in the future, but it is difficult to eliminate the volatility in the short term, so the overall investment risk is still large.

#### G. Empirical Analysis of TARCH Model

Based on the previous research, we choose the TARCH (1, 1) model to study the leverage of the fluctuation of stock price. The equation is:

$$GARCH = C(2) + C(3) * RESID(-1)^2 + C(4) * RESID(-1)^2 * (RESID(-1) < 0) + C(5) * GARCH(-1) \quad (7)$$

The mean equation is:

$$P_t = 0.0043 + 0.9995P_{t-1}$$

$$Z = (1.3640) \quad (2398.686)$$

The variance equation is:

$$\sigma_t^2 = 1.79 \times 10^{-6} + 0.0653u_{t-1}^2 + 0.0309u_{t-1}^2 d_{t-1} + 0.9156\sigma_{t-1}^2$$

$$Z = (7.3020) \quad (12.8983) \quad (4.9734) \quad (240.2412)$$

TABLE VII. ESTIMATED RESULTS OF TARCH MODEL (1,1)

Model	$\omega$	$\alpha$	$\beta$	$\gamma$
TARCH (1, 1)	$1.79 \times 10^{-6}$	0.065	0.031	0.916

In this model, all parameters of the equation have passed the test of significance, demonstrating the existence of leverage. The leverage coefficient  $\gamma$  in Table VI is not equal to 0, and its value is greater than 0, the asymmetric effect may lead to increased volatility. Good news expands to  $\alpha=0.065$  times its original impact; bad news causes  $\alpha+\gamma=0.981$  times. It is believed that favorable news has bigger impact than the same amount of bad news.

ARCH-LM residuals test of the TARCH (1, 1) model checked whether the model is significant to eliminate the conditional heteroscedasticity of autoregressive model of return rate as shown in "Fig. 7".

Heteroskedasticity Test: ARCH

F-statistic	0.462784	Prob. F(1,4903)	0.4964
Obs*R-squared	0.462929	Prob. Chi-Square(1)	0.4963

Fig. 7. ARCH-LM test results of residual series of TARCH (1, 1) model.

You can see from "Fig. 7", p value is 0.4964, higher than the significant level of 5%. Hence, we should accept the null hypothesis, and the results show no ARCH effect, the conditional heteroscedasticity of return residuals has been eliminated. It can be concluded that the TARCH (1, 1) model is qualified and can fit well.

#### H. Empirical Analysis of EARCH Model

According to the previous studies, we choose EGARCH (1, 1) model to study the asymmetry of stock price volatility. The equation would be:

$$\begin{aligned} \log(GARCH) = & C(2) + C(3) * ABS(RESID(-1)) / @SQRT \\ & (GARCH(-1)) + C(4) * RESID(-1) / @ (GARCH(-1)) + \\ & C(5) * \log(GARCH(-1)) \end{aligned} \quad (8)$$

The mean equation is:

$$P_t = 0.0023 + 0.9997P_{t-1}$$

$$Z = (0.7448) \quad (2523.807)$$

The variance equation is:



$$\ln(\sigma_t^2) = -0.2416 + 0.9873 \ln(\sigma_{t-1}^2) + 0.1789 \left| \frac{u_{t-1}}{\sigma_{t-1}} \right| - 0.0278 \frac{u_{t-1}}{\sigma_{t-1}}$$

$$Z = (-14.7147) \quad (600.1963) \quad (21.8026) \quad (-6.3470)$$

TABLE VIII. ESTIMATED RESULTS OF EARCH MODEL (1,1)

Model	$\omega$	$\alpha$	$\beta$	$\gamma$
EARCH (1, 1)	-14.715	21.803	600.196	-6.347

In this model, all parameters of the equation have passed the test of significance. Since  $C(5)$  is less than 0, that is,  $\gamma$  is not equal to 0. A good message produces  $\alpha - |\gamma| = 15.456$  times impact, meanwhile bad information can produce  $\alpha + |\gamma| = 28.150$  times, according to the results of TABLE VIII. Therefore, the influence of bad information is greater than that of good information, which can cause greater volatility.

The ARCH-LM residuals test of the EGARCH (1, 1) model is shown in "Fig. 8", and the results are analyzed to see if the model is qualified.

Heteroskedasticity Test: ARCH

F-statistic	0.530135	Prob. F(1,4903)	0.4666
Obs*R-squared	0.530293	Prob. Chi-Square(1)	0.4665

Fig. 8. ARCH-LM test results of residual series in EARCH (1, 1) model.

As shown in the figure, we can see that the P value equals around 0.4666 and we can accept the null hypothesis, which says that the model has no ARCH effect. Therefore, the model is suitable. Finally, draw an intuitive curve, see "Fig. 9".

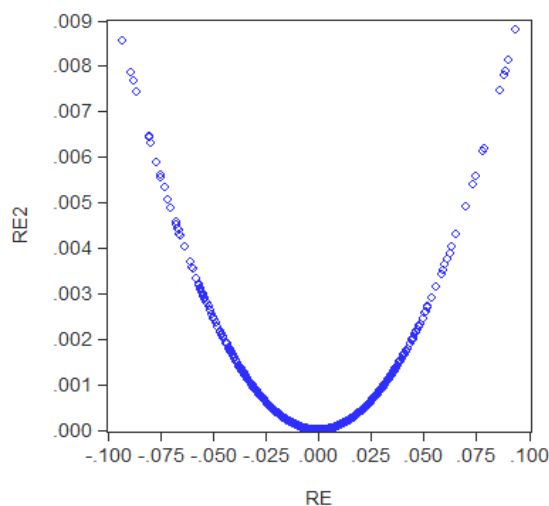


Fig. 9. Curve of information impact force.

RE sequence is  $u_{t-1}/\sigma_{t-1}$ ,  $RE^2$  sequence is  $\alpha |u_{t-1}/\sigma_{t-1}| + \gamma(u_{t-1}/\sigma_{t-1})$ . It is obvious that in the left half of the graph, when the impact of information is negative, the impact curve is relatively high in slope and thus is steeper; in the right half of

the graph, when the impact of information is positive, that is, greater than 0, the impact curve is relatively flat.

#### IV. CONCLUSION

- The log return rate series of China's Shanghai composite index has the characteristics of leptokurtosis and fat-tail. The volatility of the stock market has higher investment risk. The stock index volatility bears "cluster" traits and financial time series is stable and has conditional heteroscedasticity, the asymmetry and leverage effect either.
- Shanghai stock return rate series has significant autocorrelation, it shows that Chinese stock market has not achieved a weak efficiency stock market yet. Return series is stable and suitable to take advantage of GARCH model to describe ARCH effect. After repeated testing and inspection, the  $p=q=1$  model is more suitable and excellent, for it fits the volatility research of log return rate series, and can achieve better goodness of fit.
- Through the analysis, several characteristics of fluctuation indicate that more speculative and irrational behaviors occur among most of investors. The frequency of "chase the winner, cut the loser" is still high. Investors facing the negative information lack the ability to look at the stock market in the long run. Sometimes it is very difficult to let them restore confidence and look at the stock market with optimism in a short period of time. What's more, the existing information will help and predict the future trend and situation. However, it is difficult to eliminate fluctuations in the short term, so the overall investment risk is still large.
- Empirical results show that TARCH and EGARCH model provide even starker proof for the conclusion that stock return rate volatility has obvious leverage effect. Also, the size of the impact can be represented more clearly. Bad information will have a greater impact on the stock market than positive information. Mainly because the ability of Chinese investors to bear risks is relatively low, and they are sensitive to the bad news, also have the poor understanding of the stock investment.
- The stock market in China is still less developed than many foreign early mature securities markets. Many aspects need to be improved and sharpened. After a series of tests and examinations, it is also concluded that the GARCH model has advantages in depicting the trend of Shanghai composite index return rate.

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