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Correlation Analysis of Three Stock Markets - Shanghai, Shenzhen, and Hong Kong

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Abstract

The volatility of financial markets and the emergence of financial crisis in recent years have made the financial markets' correlation analysis to become the focus of researchers worldwide. In this paper we use GARCH model to analyze data of Shanghai composite index, Shenzhen component index, and Hong Kong index on the day's closing prices for the period January 1, 2005 to December 31, 2012. During this study we a) explore the correlation in between the said three stock markets and the influences that each market has on the others, b) observe the basic statistical characteristic analysis of the return and unit root stationary test of yield sequence, and analyze three cities tertian yield change of cause and effect using GRANGER causality test, and c) perform the parameter estimation, modeling, and fitting of GARCH model. We find that indices of said three stock markets are correlated. This study concludes that GARCH(1, 1)-GED model fits all the three stock markets better. The findings of this study may be helpful for the investors in their investment decisions in relevant markets.

Keywords: *ADF test; GRANGER causality test; ARCH effect; GARCH(1,1) model*

1. Introduction

With the continuous development of economic and financial markets and with their growing mutual influences and interdependences, the globalization and openness are on a continuing rise. That is why the study of the stock market conditions to identify the present situation and to analyze the prospective economic outlook has gained greater significances. The international financial markets may either have asymmetric or non-normal characteristics. If the Copulas function theory is applied to financial markets, the correlation analysis between the financial markets may have unique advantages [1].

Robert Engle [2] presented the Autoregressive Conditional Heteroscedasticity (ARCH) model in 1982. The ARCH model was a very good fitting for fluctuations that existed in the data gathered, and could also reflect the rush fat-tailed features, however, the weakness was that the lag of the ARCH model was difficult to determine. Bollerslev [3] put forward the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model in 1986 which assumed that the sequence of conditional variances of random error is connected with the error term of the early stage of the conditional variance value; this solved the problem associated with the ARCH model. Later on, Engle, Lilien, and Robins [4] studied the volatility influence on the yield sequence in 1987 and further improved the ARCH model.

In China, using the GARCH model, Chen Meixiang and Sun Wei [5], modeled the stock yield sequence of Shenzhen composite index in year 2009. In 2002, WenSubin [6] provided statistical description of China's stock index and showed that China's financial assets yielded the characteristics of Autoregressive Conditional Heteroscedasticity and demonstrated the normality.

2. The Empirical Analysis for Shanghai, Shenzhen, and Hong Kong Stock Markets

2.1. Stock Price Index and the Data Selection

Stock price index or stock index or index, is a kind of relative abundance that can reflect the change of stock price trends. Usually we use "dot" to represent the unit of the stock price index. The rise and fall of stock price index can be used by investors. The investors can use stock index to judge the trends of stock price changes, and can also use stock index to reflect the trends of the stock market [7].

This paper uses the daily closing prices from January 1, 2005 to December 31, 2012 for Shanghai stock market composite index, Shenzhen component index, and Hong Kong's hang sheng index for data analysis. For reader's clarity it is noted that, in China, Hong Kong is sometimes also known as XIANG. For analysis reasons, a sample size of 1884 has been taken and the dates having inconsistent data sets are eliminated. The source of data is wind information system of China [8]. Except for the Normality Analysis which is founded on SPSS, all the other analysis are based on EVIEWS.

2.2. Fundamental Statistics Analysis [9]

Table 1. Basic Statistical Data of Shanghai, Shenzhen, and Hong Kong

Sample	Min	Max	Mean	Std. Dev.	Skewness	Kurtosis	J-B	P
Shanghai	-9.256	9.035	0.032	1.826	-0.243	6.106	775.648	0.0
Shenzhen	-9.750	9.162	0.059	2.040	-0.250	5.177	391.615	0.0
Hong Kong	-13.58	13.41	0.025	1.757	-0.023	11.91	6229.98	0.0

Table 1 gives the basic statistical characteristics of Shanghai, Shenzhen, and Hong Kong. From the statistics, we can observe that the maximum value, standard deviation, and the absolute value of the minimum value of Shenzhen stock market are greater than the Shanghai's stock market in the same period. We can explain that Shenzhen is more volatile than Shanghai stock market. While the absolute value of the minimum value and the maximum value of Hong Kong stock market are greater than the Shenzhen stock market in the same period, the mean and standard deviation are smaller than the other two markets. The standard deviations and the average of Shanghai, Shenzhen and Hong Kong markets are small; all their skew ness coefficients are negative; this shows that the sequences of yield of the Shanghai, Shenzhen and Kong exhibit the characteristic of the left tail; all their kurtosis coefficients are greater than 3, this shows that the sequences of yield of the Shanghai, Shenzhen and Hong Kong have the characteristics of the peak.

2.3. Volatility Analysis [10]

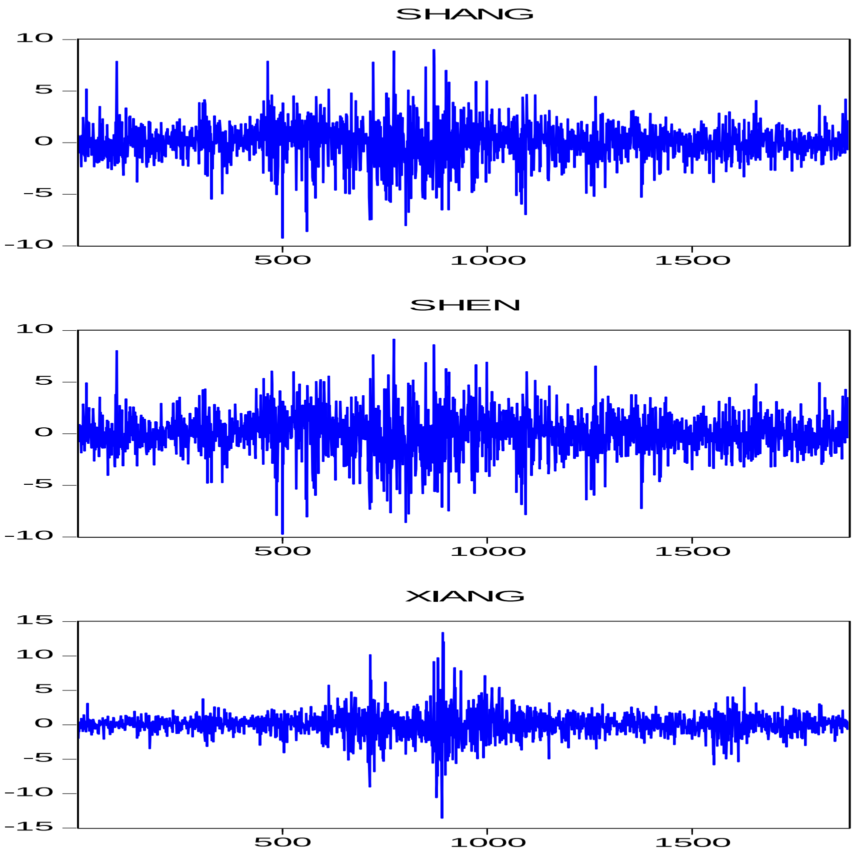


Figure 1. The Trend Chart of the Sequences of Yield of Shanghai, Shenzhen, and Hong Kong

Figure 1 shows the trend chart of the sequences of yield of Shanghai, Shenzhen, and Hong Kong (*i.e.*, volatility chart). We can see from the diagram, the sequences of yield of Shanghai, Shenzhen, and Hong Kong markets are showing more significant "cluster phenomenon", *i.e.*, the small fluctuations are followed by small fluctuations, and vice versa. From the point of fluctuation frequency and extent, the sequences of Shanghai and Shenzhen show relatively consistent trend with a certain degree of similarity. We conclude that stock indices of Shanghai and Shenzhen have high relevance.

2.4. Normality Analysis [11]

Using SPSS software, we get the Normality test of the sequences of yield of Shanghai, Shenzhen, and Hong Kong; and we get Table 2.

Table 2. K-S Test Results

	Kolmogorov-Smirnov	df	Asymptom. Sig.
Shanghai	3.388	1884	.000
Shenzhen	2.572	1884	.000
Hong Kong	3.858	1884	.000

We can see from Table 2 that under a given significant level, the sig. is obviously less than 0.01, and so the normal distribution assumption is rejected.

2.5. GRANGER Causal Analysis

2.5.1. Unit Root Test [12]

Table 3. ADF Test Results of Shanghai, Shenzhen, and Hong Kong

Sample	ADF value	1% Critical value	5% Critical value	10% Critical value	P	Result
Shanghai	-17.65820	-3.962928	-3.412199	-3.128025	0.000	smooth
Shenzhen	-24.02447	-3.962928	-3.412199	-3.128025	0.000	smooth
Hong Kong	-25.55074	-3.962928	-3.412199	-3.128025	0.000	smooth

We can comprehend from Table 3 that the Augmented Dickey-Fuller (ADF) test value of the yield sequence of Shanghai, Shenzhen, and Hong Kong are greater than the absolute value of the critical value for 1%, 5% and 10% significant levels. Consequently, the null hypothesis of the unit root is excluded, so sequences are smooth.

2.5.2. GRANGER Causality Test Results [13]

This article selects Lags period of 1 to 15 and gets the GRANGER causality test results which are shown in Table 4, 5, 6respectively.

Table 4. GRANGER Causality Test Results of Shanghai and Shenzhen

	Lags	GRANGER	F value	P	Conclusion
Shanghai and Shenzhen	1	SHEN is not reason of SHANG SHANG is not reason of SHEN	0.92549 6.04464	0.3362 0.0140	accept refuse
	2	SHEN is not reason of SHANG SHANG is not reason of SHEN	0.52756 4.10017	0.5901 0.0167	accept refuse
	3	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.32107 2.77122	0.2658 0.0402	accept refuse
	4	SHEN is not reason of SHANG SHANG is not reason of SHEN	0.94106 2.51893	0.4391 0.0395	accept refuse
	5	SHEN is not reason of SHANG SHANG is not reason of SHEN	0.85682 2.51019	0.5095 0.0283	accept refuse
	6	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.49364 3.37921	0.1764 0.0026	accept refuse
	7	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.30312 2.79519	0.2447 0.0068	accept refuse
	8	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.14759 2.47826	0.3279 0.0113	accept refuse
	9	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.07154 2.29223	0.3807 0.0148	accept refuse
	10	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.02368 2.04134	0.4205 0.0261	accept refuse
	11	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.30153 2.50827	0.2170 0.0039	accept refuse
	12	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.44359 2.52109	0.1390 0.0027	accept refuse
	13	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.35128 2.62063	0.1760 0.0013	accept refuse
	14	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.31309 2.65959	0.1912 0.0007	accept refuse
	15	SHEN is not reason of SHANG SHANG is not reason of SHEN	1.58709 2.90760	0.0697 0.0001	accept refuse

Table 5. GRANGER Causality Test Results of Shanghai and Hong Kong

	Lags	GRANGER	F value	P	Conclusion
Shanghai and Hong Kong	1	XIANG is not reason of SHANG	1.14854	0.2840	accept
		SHANG is not reason of XIANG	10.0583	0.0015	refuse
	2	XIANG is not reason of SHANG	0.55589	0.5737	accept
		SHANG is not reason of XIANG	5.17588	0.0057	refuse
	3	XIANG is not reason of SHANG	0.35037	0.7889	accept
		SHANG is not reason of XIANG	3.54500	0.0140	refuse
	4	XIANG is not reason of SHANG	0.42881	0.7879	accept
		SHANG is not reason of XIANG	2.60044	0.0345	refuse
	5	XIANG is not reason of SHANG	0.66670	0.6488	accept
		SHANG is not reason of XIANG	3.34985	0.0051	refuse
	6	XIANG is not reason of SHANG	1.51768	0.1684	accept
		SHANG is not reason of XIANG	3.59560	0.0015	refuse
	7	XIANG is not reason of SHANG	1.35853	0.2188	accept
		SHANG is not reason of XIANG	4.10339	0.0002	refuse
	8	XIANG is not reason of SHANG	1.59994	0.1198	accept
		SHANG is not reason of XIANG	3.57338	0.0004	refuse
	9	XIANG is not reason of SHANG	1.51921	0.1354	accept
		SHANG is not reason of XIANG	3.11551	0.0010	refuse
	10	XIANG is not reason of SHANG	1.88582	0.0428	accept
		SHANG is not reason of XIANG	3.36118	0.0002	refuse
	11	XIANG is not reason of SHANG	1.71479	0.0645	accept
		SHANG is not reason of XIANG	3.10408	0.0004	refuse
	12	XIANG is not reason of SHANG	1.63647	0.0753	accept
		SHANG is not reason of XIANG	2.85998	0.0007	refuse
	13	XIANG is not reason of SHANG	1.63565	0.0690	accept
		SHANG is not reason of XIANG	2.62793	0.0012	refuse
	14	XIANG is not reason of SHANG	1.50942	0.0996	accept
		SHANG is not reason of XIANG	2.49317	0.0016	refuse
	15	XIANG is not reason of SHANG	1.39863	0.1389	accept
		SHANG is not reason of XIANG	2.40664	0.0018	refuse

Table 6. GRANGER Causality Test Results of Shenzhen, and Hong Kong

	Lags	GRANGER	F value	P	Conclusion
Shenzhen, and Hong Kong	1	XIANG is not reason of SHEN	0.22602	0.6345	accept
		SHEN is not reason of XIANG	9.85671	0.0017	refuse
	2	XIANG is not reason of SHEN	0.37312	0.6886	accept
		SHEN is not reason of XIANG	5.05122	0.0065	refuse
	3	XIANG is not reason of SHEN	0.14429	0.9334	accept
		SHEN is not reason of XIANG	3.55789	0.0138	refuse
	4	XIANG is not reason of SHEN	0.21450	0.9305	accept
		SHEN is not reason of XIANG	2.92117	0.0201	refuse
	5	XIANG is not reason of SHEN	0.32357	0.8990	accept
		SHEN is not reason of XIANG	2.60570	0.0234	refuse
	6	XIANG is not reason of SHEN	0.44719	0.8473	accept
		SHEN is not reason of XIANG	2.30824	0.0318	refuse
	7	XIANG is not reason of SHEN	0.45071	0.8702	accept
		SHEN is not reason of XIANG	3.00473	0.0039	refuse
	8	XIANG is not reason of SHEN	0.52269	0.8402	accept
		SHEN is not reason of XIANG	2.60405	0.0078	refuse
	9	XIANG is not reason of SHEN	0.68970	0.7189	accept
		SHEN is not reason of XIANG	2.28627	0.0151	refuse
	10	XIANG is not reason of SHEN	0.98922	0.4504	accept
		SHEN is not reason of XIANG	2.73973	0.0024	refuse

	11	XIANG is not reason of SHEN SHEN is not reason of XIANG	0.91861 2.47617	0.5213 0.0044	accept refuse
	12	XIANG is not reason of SHEN SHEN is not reason of XIANG	0.89430 2.28880	0.5522 0.0069	accept refuse
	13	XIANG is not reason of SHEN SHEN is not reason of XIANG	0.95865 2.14060	0.4905 0.0100	accept refuse
	14	XIANG is not reason of SHEN SHEN is not reason of XIANG	0.89597 2.06565	0.5629 0.0112	accept refuse
	15	XIANG is not reason of SHEN SHEN is not reason of XIANG	0.82922 1.95558	0.6455 0.0151	accept refuse

If the critical value P is greater than 0.05 under the confidence level of 95%, the null hypothesis occurs with a larger probability, and so we accept the null hypothesis.

It is concluded from the Table 4 that under the confidence level of 95% the Shanghai index is a GRANGER cause of the Shenzhen index but the Shenzhen index is not the GRANGER cause of Shanghai index. This indicates that the Shanghai stock market have significant GRANGER guide for Shenzhen stock market prediction. If we only use the Shenzhen stock market past information to predict the future trend, the Shanghai stock market information can be used for future trends of Shenzhen stock market but the reverse is not possible. Therefore we conclude that Shanghai and Shenzhen have asymmetric volatility spillover effect.

In the similar way, it may be concluded from the Tables 5 and 6 that Shanghai and Hong Kong have asymmetric volatility spillover effect; likewise Shenzhen and Hong Kong also have asymmetric volatility spillover effect.

3. GARCH Model Research for Three Market Yields Sequence

3.1. Correlation Analysis [14]

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.001	0.001	0.0009	0.976
		2	-0.009	-0.009	0.1516	0.927
		3	0.044	0.044	3.8251	0.281
		4	0.038	0.038	6.6132	0.158
		5	0.005	0.006	6.6614	0.247
		6	-0.051	-0.052	11.544	0.073
		7	0.015	0.012	11.964	0.102
		8	0.008	0.006	12.097	0.147
		9	-0.004	0.000	12.129	0.206
		10	0.049	0.052	16.743	0.080

Figure 2. The Correlation Analysis Shanghai Index Yield Sequence r_t

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.127	0.127	30.377	0.000
		2	0.082	0.067	43.010	0.000
		3	0.142	0.127	81.165	0.000
		4	0.129	0.096	112.52	0.000
		5	0.104	0.066	132.96	0.000
		6	0.128	0.086	164.11	0.000
		7	0.141	0.090	201.53	0.000
		8	0.093	0.036	217.99	0.000
		9	0.087	0.030	232.39	0.000
		10	0.159	0.101	280.14	0.000

Figure 3. The Correlation Analysis Shanghai index Yield Sequence r_t^2

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.042	0.042	3.3830	0.066
		2	-0.024	-0.026	4.4644	0.107
		3	0.043	0.045	7.9264	0.048
		4	0.030	0.026	9.6755	0.046
		5	-0.006	-0.006	9.7346	0.083
		6	-0.036	-0.037	12.254	0.057
		7	0.031	0.031	14.042	0.050
		8	-0.006	-0.011	14.109	0.079
		9	0.014	0.020	14.467	0.107
		10	0.059	0.056	20.973	0.021

Figure 4. The Correlation Analysis Shenzhen Index Yield Sequence r_t

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.109	0.109	22.399	0.000
		2	0.096	0.085	39.769	0.000
		3	0.112	0.095	63.382	0.000
		4	0.123	0.098	92.133	0.000
		5	0.090	0.056	107.56	0.000
		6	0.110	0.073	130.26	0.000
		7	0.162	0.122	179.84	0.000
		8	0.134	0.083	213.82	0.000
		9	0.062	0.002	221.02	0.000
		10	0.107	0.051	242.87	0.000

Figure 5. The Correlation Analysis Shenzhen Index Yield Sequence r_t^2

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.038	-0.038	2.6638	0.103
		2	0.012	0.011	2.9576	0.228
		3	-0.017	-0.016	3.4729	0.324
		4	-0.031	-0.032	5.2993	0.258
		5	-0.012	-0.014	5.5730	0.350
		6	-0.041	-0.042	8.8066	0.185
		7	0.015	0.011	9.2189	0.237
		8	0.044	0.045	12.897	0.115
		9	-0.036	-0.035	15.333	0.082
		10	-0.039	-0.046	18.247	0.051

Figure 6. The Correlation Analysis Hong Kong Index Yield Sequence r_t

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.401	0.401	302.88	0.000
		2	0.357	0.234	543.42	0.000
		3	0.345	0.178	767.84	0.000
		4	0.251	0.032	886.92	0.000
		5	0.192	-0.008	956.82	0.000
		6	0.199	0.049	1032.1	0.000
		7	0.203	0.073	1110.1	0.000
		8	0.250	0.132	1228.6	0.000
		9	0.208	0.027	1310.3	0.000
		10	0.304	0.156	1485.0	0.000

Figure 7. The Correlation Analysis Hong Kong Index Yield Sequence r_t^2

From Figure 2 we see that the sequence of yield of the Shanghai index r_t of autocorrelation function (ACF) and partial autocorrelation function (PACF) are very weak. Similarly, from Figure 3 we observe that the sequence of yield of the Shanghai index r_t^2 of autocorrelation function (ACF) and partial autocorrelation function (PACF) are very strong. We can get the following conclusion: the sequence of yield of the Shanghai composite index may have the ARCH effect, so it is necessary to test the ARCH effect on the sequence of yield of the Shanghai index.

In the same way, it is concluded from the Figures 4 to 7 that: Shenzhen, and Hong Kong also have the ARCH effect.

3.2. Conditional Heteroscedasticity Test (ARCH effects)

Now we take the Lagrange Multiplier (LM) test for the residual sequence of Shanghai, Shenzhen, and Hong Kong; the order is 1~15.

Table 7. The LM Test Results of the Residual Sequences of Three Market with Order 1~15

Lags	Shanghai LM	Shenzhen LM	Hong Kong LM	P
1	29.81783	21.69686	304.4486	0.0000
2	38.45464	35.83899	389.3428	0.0000
3	68.21088	52.59807	437.5153	0.0000
4	85.03912	69.91111	438.7077	0.0000
5	92.60098	75.06499	438.5042	0.0000
6	105.6609	84.50443	441.6131	0.0000
7	119.9850	111.5950	449.1133	0.0000
8	122.1878	123.8007	473.7283	0.0000
9	123.8602	123.7677	474.4628	0.0000
10	141.5163	128.0164	508.5821	0.0000
11	142.4852	130.0641	510.6735	0.0000
12	142.6480	130.0235	511.7077	0.0000
13	151.8805	140.0061	534.3940	0.0000
14	153.1050	142.9266	545.8567	0.0000
15	152.9920	143.6660	546.0586	0.0000

From Table 7 we find that when $q \geq 1$, the probability of LM statistics of the residual sequence of three markets are 0; all less than the probability in the significant level $\alpha = 0.05$. So we reject the original hypothesis H_0. We conclude that there exist conditional heteroscedasticity of the residual sequences of three markets, *i.e.*, $\{\varepsilon_t\}$ exist at a higher order of the ARCH effect. Due to this higher order, ARCH model can be replaced with a lower order GARCH model. Therefore we use GARCH in order to model Shanghai, Shenzhen, and Hong Kong sequences.

3.3. GARCH Model

3.3.1. GARCH (1, 1) Model Parameter Estimation and Selection [15]: If we use GARCH model, the yield sequence will usually lead to rush thick tail. So if the conditional distribution of residuals follows a standard normal distribution it may lead to a larger estimation error. That is why we do not use GARCH-N model. On the other hand, if the conditional distribution follows the non-normal case, then we can use certain other variants such as GARCH-M, GARCH-t, and GARCH-GED. If residuals are assumed to be mean distribution (*i.e.*, GARCH-M) or t-distribution (*i.e.*, GARCH-t), they follow the characteristics of sharp peak tip and the tail hypertrophy as compared to the normal distribution. If residuals are assumed to follow the GED distribution (*i.e.*, GARCH-GED) then the tail is thicker than the normal distribution, and the peak is sharper as compared to the normal distribution.

A large number of studies have shown that GARCH(1,1)-M model, GARCH(1,1)-t model, and GARCH(1,1)-GED model can better depict the yield sequence of the stock market's statistical characteristics such as peak, time-varying, skew ness, thick-tail *etc.*. Based on the above three models, we now model the yield sequence of Shanghai, Shenzhen, and Hong Kong stock markets. Parameters of the models are shown as below.

GARCH (1, 1)-M model:

$$r_t = \mu + a_t$$

$$a_t = \sigma_t \varepsilon_t, \varepsilon_t \mid I_{t-1} \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \beta \sigma_{t-1}^2$$

GARCH (1, 1)-t model:

$$r_t = \mu + a_t$$

$$a_t = \sigma_t \varepsilon_t, \sqrt{\frac{v}{\sigma_t^2 (v-2)}} \varepsilon_t \mid I_{t-1} \sim t_v$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \beta \sigma_{t-1}^2$$

GARCH (1, 1)-GED model:

$$r_t = \mu + a_t$$

$$a_t = \sigma_t \varepsilon_t, a_t \mid I_{t-1} \sim GED\left(0, \sigma_t^2, \lambda\right)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \beta \sigma_{t-1}^2$$

Using the EVIEWS 6.0 software, the results for three markets under study are displayed in Table 8, 9, and 10 respectively.

Table 8. The Parameter Estimation Results of Shanghai

Shanghai			
Model	**GARCH(1,1)-M**	**GARCH(1,1)-t**	**GARCH(1,1)-GED**
μ	0.037377 0.031799	0.067434 0.031492	0.075975 0.029518
α_0	0.028307 0.006418	0.020304 0.009270	0.022875 0.010011
α_1	0.050209 0.006121	0.046551 0.009353	0.048267 0.009908
β	0.941778 0.006781	0.949200 0.009706	0.945494 0.010718
likelihood	-3616.780	-3556.078	-3553.345
AIC	3.843716	3.780337	3.777437
SC	3.855481	3.795043	3.792143

We can see from Table 8 that all the model parameters for Shanghai are significant, so using the GARCH (1, 1)-M, GARCH (1, 1)-t, and GARCH (1, 1)-GED to model yield sequence are appropriate. Compared to GARCH (1, 1)-M (or GARCH (1, 1) –t) model, for Shanghai, the GARCH (1, 1) -GED model has more logarithmic likelihood value, and smaller AIC and SC values. Consequently GARCH (1, 1)-GED model yields has higher fitting degree. Therefore we chose GARCH (1, 1)-GED to describe the Shanghai stock market.

So, GARCH (1, 1)-GED model of Shanghai may be given as follows.

$$r_t = 0.075975 + a_t$$
$$a_t = \sigma_t \varepsilon_t, a_t \mid I_{t-1} \sim GED\left(0, \sigma_t^2, \lambda\right)$$
$$\sigma_t^2 = 0.022875 + 0.048267 a_{t-1}^2 + 0.945494 \sigma_{t-1}^2$$

Table 9. The Parameter Estimation Results of Shenzhen

Shenzhen			
Model	**GARCH(1,1)-M**	**GARCH(1,1)-t**	**GARCH(1,1)-GED**
μ	0.053073 0.038984	0.067769 0.037934	0.066616 0.036530
α_0	0.045924 0.010515	0.038771 0.015162	0.042338 0.015851
α_1	0.047772 0.006439	0.045761 0.009525	0.046606 0.009713
β	0.941339 0.007426	0.946035 0.010689	0.943384 0.011174
likelihood	-3871.699	-3835.673	-3832.432
AIC	4.114330	4.077148	4.073707
SC	4.126095	4.091854	4.088413

Table 10. The Parameter Estimation Results of Hong Kong

Hong Kong			
Model	**GARCH(1,1)-M**	**GARCH(1,1)-t**	**GARCH(1,1)-GED**
μ	0.071739 0.026145	0.081193 0.025411	0.079612 0.024512
α_0	0.018820 0.004793	0.011643 0.005650	0.013260 0.006087
α_1	0.079709 0.008477	0.074892 0.011465	0.076409 0.012004
β	0.913422 0.008926	0.923259 0.011166	0.920276 0.012077
likelihood	-3251.429	-3227.159	-3221.481
AIC	3.455869	3.431166	3.425140
SC	3.467634	3.445872	3.439845

In the same way, looking at Table 9 and 10, we chose GARCH (1, 1)-GED model to describe the Shenzhen, and Hong Kong stock markets.

So GARCH (1, 1)-GED model for Shenzhen is

$$r_t = 0.066616 + a_t$$
$$a_t = \sigma_t \varepsilon_t, a_t \mid I_{t-1} \sim GED\left(0, \sigma_t^2, \lambda\right)$$
$$\sigma_t^2 = 0.042338 + 0.046606 a_{t-1}^2 + 0.943384 \sigma_{t-1}^2$$

And GARCH (1, 1)-GED model for Hong Kong is

$$r_t = 0.079612 + a_t$$

$$a_t = \sigma_t \varepsilon_t, a_t \mid I_{t-1} \sim GED\left(0, \sigma_t^2, \lambda\right)$$

$$\sigma_t^2 = 0.013260 + 0.076409 a_{t-1}^2 + 0.920276 \sigma_{t-1}^2$$

3.3.2. GARCH (1, 1)-GED model test: Now we come to residual error test and the square of the residual test of GARCH (1, 1)–GED model.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.014	0.014	0.3705	0.543
		2	-0.005	-0.005	0.4174	0.812
		3	0.064	0.064	8.0541	0.045
		4	0.009	0.007	8.1962	0.085
		5	0.020	0.021	8.9858	0.110
		6	-0.048	-0.053	13.373	0.037
		7	0.048	0.049	17.693	0.013
		8	0.020	0.015	18.426	0.018
		9	-0.002	0.005	18.431	0.030
		10	0.065	0.060	26.421	0.003
		11	0.011	0.008	26.644	0.005
		12	0.023	0.019	27.664	0.006
		13	0.027	0.023	29.043	0.006
		14	0.039	0.036	31.907	0.004
		15	0.038	0.031	34.632	0.003

Figure 8. The Correlation Analysis of GARCH (1, 1)-GED Model of Shanghai index Yield Sequence r_t

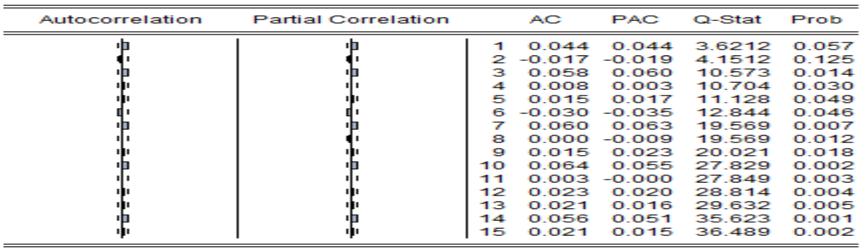
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.016	-0.016	0.4989	0.480
		2	-0.003	-0.003	0.5138	0.773
		3	-0.008	-0.008	0.6326	0.889
		4	0.014	0.014	0.9932	0.911
		5	0.005	0.005	1.0365	0.960
		6	0.002	0.002	1.0415	0.984
		7	-0.000	-0.000	1.0417	0.994
		8	-0.014	-0.014	1.4120	0.994
		9	0.006	0.005	1.4725	0.997
		10	0.064	0.064	9.1459	0.518
		11	-0.021	-0.019	9.9769	0.532
		12	0.020	0.020	10.747	0.551
		13	0.028	0.029	12.210	0.511
		14	-0.011	-0.012	12.440	0.571
		15	-0.020	-0.020	13.227	0.585

Figure 9. The Correlation Analysis of GARCH (1, 1)-GED Model of Shanghai Index Yield Sequence r_t^2

Table 11. The LM Test Results of the Residual Sequences of GARCH (1, 1)-GED Model of Shanghai with Order 1~15

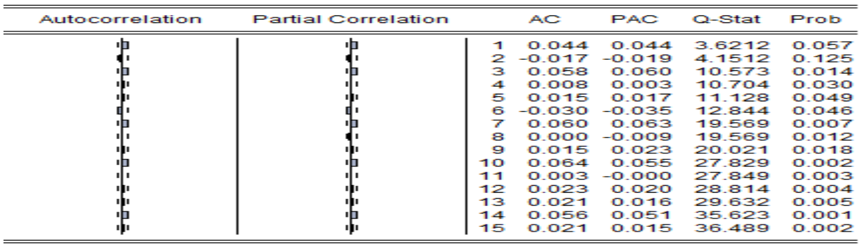
Lags	Shanghai LM	P
1	0.497894	0.4804
2	0.513411	0.7736
3	0.629777	0.8896
4	0.978532	0.9130
5	1.029226	0.9602
6	1.050038	0.9836
7	1.057200	0.9939
8	1.427193	0.9939
9	1.517515	0.9970
10	9.262959	0.5073
11	9.952350	0.5347
12	10.72514	0.5526
13	12.34500	0.4996
14	12.64666	0.5545
15	13.43782	0.5685

Figure 8 shows that the PAC and AC of the residual error of GARCH (1, 1)-GED of Shanghai are in random interval; this shows that residual error of the GARCH (1, 1)-GED model is not relevant. Figure9 shows that the PAC and AC of the residual square of GARCH(1, 1)-GED of Shanghai are in random interval; this shows that residual square of the GARCH(1, 1)-GED model is also not relevant.Table11 shows the residual test results of the ARCH effect of GARCH(1, 1)-GED model of Shanghai. We find that the associated probability of LM statistics were significantly greater than 0.05; it shows that residual have no ARCH effect. So we conclude that using GARCH (1, 1)-GED model to model Shanghai stock market is feasible.



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.044	0.044	3.6212	0.057
		2	-0.017	-0.019	4.1512	0.125
		3	0.058	0.060	10.573	0.014
		4	0.008	0.003	10.704	0.030
		5	0.015	0.017	11.128	0.049
		6	-0.030	-0.035	12.844	0.046
		7	0.060	0.063	19.569	0.007
		8	0.000	-0.009	19.569	0.012
		9	0.015	0.023	20.021	0.018
		10	0.064	0.055	27.829	0.002
		11	0.003	-0.000	27.849	0.003
		12	0.023	0.020	28.814	0.004
		13	0.021	0.016	29.632	0.005
		14	0.056	0.051	35.623	0.001
		15	0.021	0.015	36.489	0.002

Figure 10. The Correlation Analysis of GARCH (1, 1)-GED Model of Shenzhen Index Yield Sequence r_t



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.044	0.044	3.6212	0.057
		2	-0.017	-0.019	4.1512	0.125
		3	0.058	0.060	10.573	0.014
		4	0.008	0.003	10.704	0.030
		5	0.015	0.017	11.128	0.049
		6	-0.030	-0.035	12.844	0.046
		7	0.060	0.063	19.569	0.007
		8	0.000	-0.009	19.569	0.012
		9	0.015	0.023	20.021	0.018
		10	0.064	0.055	27.829	0.002
		11	0.003	-0.000	27.849	0.003
		12	0.023	0.020	28.814	0.004
		13	0.021	0.016	29.632	0.005
		14	0.056	0.051	35.623	0.001
		15	0.021	0.015	36.489	0.002

Figure 11.The Correlation Analysis of GARCH (1, 1)-GED Model of Shenzhen Index Yield Sequence r_t^2

Table 12. The LM Test Results of the Residual Sequences of GARCH (1, 1)-GED Model of Shenzhen with Order 1~15

Lags	Shenzhen LM	P
1	1.143778	0.2849
2	1.352261	0.5086
3	2.309148	0.5108
4	2.347644	0.6721
5	2.849698	0.7231
6	2.925539	0.8181
7	5.062757	0.6523
8	5.376121	0.7167
9	5.812351	0.7585
10	7.099530	0.7160
11	8.212873	0.6941
12	9.747970	0.6381
13	11.67873	0.5541
14	11.86585	0.6171
15	11.96759	0.6815

Similarly from Figure 10, 11, and Table 12 we conclude that using GARCH (1, 1)-GED model to model Shenzhen stock market is feasible.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.000	0.000	0.0001	0.991
		2	-0.004	-0.004	0.0345	0.983
		3	0.037	0.038	2.6908	0.442
		4	-0.011	-0.011	2.9256	0.570
		5	-0.023	-0.023	3.9555	0.556
		6	-0.061	-0.063	11.049	0.087
		7	0.039	0.040	13.899	0.053
		8	-0.003	-0.002	13.921	0.084
		9	0.009	0.013	14.060	0.120
		10	-0.023	-0.028	15.023	0.131
		11	0.007	0.006	15.116	0.177
		12	0.009	0.006	15.264	0.227
		13	0.018	0.025	15.863	0.257
		14	-0.005	-0.008	15.909	0.319
		15	0.003	0.003	15.930	0.387

Figure 12. The Correlation Analysis of GARCH (1, 1)-GED Model of Hong Kong Index Yield Sequence r_t

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.000	0.000	0.0001	0.991
		2	-0.004	-0.004	0.0345	0.983
		3	0.037	0.038	2.6908	0.442
		4	-0.011	-0.011	2.9256	0.570
		5	-0.023	-0.023	3.9555	0.556
		6	-0.061	-0.063	11.049	0.087
		7	0.039	0.040	13.899	0.053
		8	-0.003	-0.002	13.921	0.084
		9	0.009	0.013	14.060	0.120
		10	-0.023	-0.028	15.023	0.131
		11	0.007	0.006	15.116	0.177
		12	0.009	0.006	15.264	0.227
		13	0.018	0.025	15.863	0.257
		14	-0.005	-0.008	15.909	0.319
		15	0.003	0.003	15.930	0.387

Figure 13. The Correlation Analysis of GARCH (1, 1)-GED Model of Hong Kong Index Yield Sequence r_t^2

Table 13. The LM Test Results of the Residual Sequences of GARCH (1, 1)-GED Model of Hong Kong with Order 1~15

Lags	Hong Kong LM	P
1	1.056197	0.3041
2	1.101486	0.5765
3	4.067799	0.2542
4	4.310853	0.3656
5	5.114332	0.4021
6	6.511690	0.3684
7	9.615395	0.2114
8	9.986483	0.2660
9	10.68564	0.2979
10	13.60095	0.1920
11	14.90065	0.1871
12	15.07651	0.2373
13	15.06966	0.3030
14	15.06758	0.3736
15	15.47620	0.4177

Also, from Figure 12, 13, and Table 13 we conclude that using GARCH (1, 1)-GED model to model Hong Kong stock market is feasible.

3.3.3. The Fitting of GARCH (1, 1)-GED Model

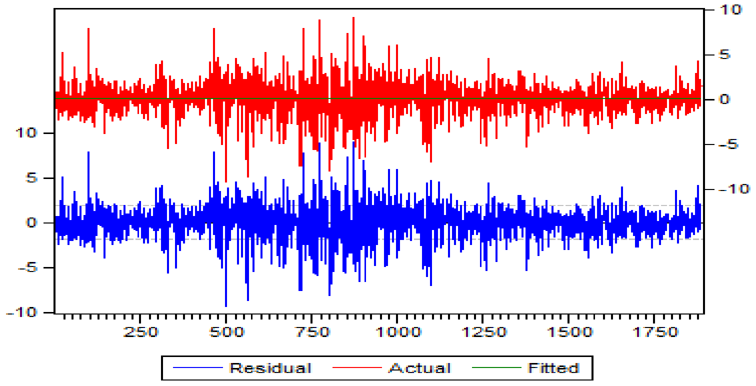


Figure 14. The Fitting of Logarithm Yield of the GARCH (1, 1)-GED Model of Shanghai

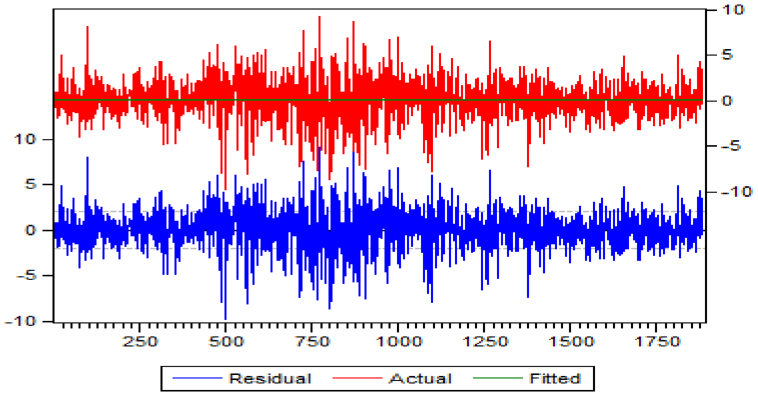


Figure 15. The Fitting of Logarithm Yield of the GARCH (1, 1)-GED Model of Shenzhen

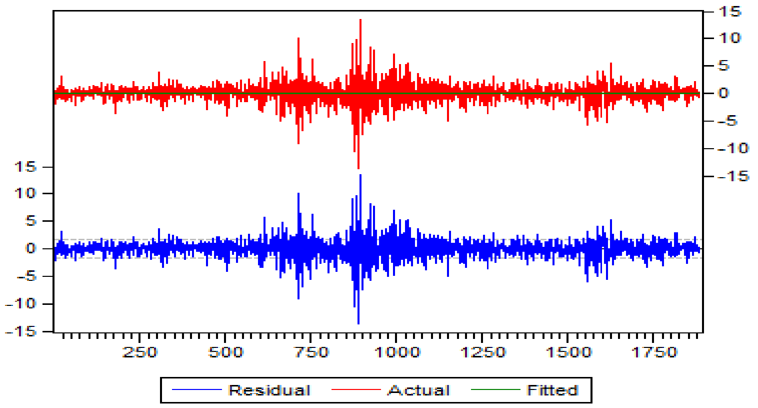


Figure 16. The Fitting of Logarithm Yield of the GARCH (1, 1)-GED Model of Hong Kong

Figure 14, 15, and 16, illustrate that using GARCH (1, 1)-GED model for fitting three markets is good.

4. Conclusion

In this paper, three stock markets namely Shanghai, Shenzhen, and Hong Kong were taken as the research object. Utilizing related statistics and finance theories, we performed a detailed analysis for said markets. The data we used consisted of the day's closing prices from January 1, 2005 to December 31, 2012. We used SPSS and EVIEWS to perform basic data analysis and concluded the following: a) the sequences of yield of the three stock markets have the characteristics of the peak, b) the sequences of yield of the three stock markets do not fit the normal distribution, c) the sequences of yield of the three stock markets are smooth, d) the sequences of yield of the three stock markets have asymmetric volatility spillover effect, and e) the sequence of yield of the three stock markets may have the ARCH effect. Finally we conclude that the fitting effect of GARCH (1, 1)-GED model for the three stock markets is found meaningful, and hence we may use GARCH (1, 1)-GED to model the three stock markets. The findings of above study may be helpful for the existing investors of said three markets as well as for those who are planning to invest in near future.

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