

The Influence of Crude Oil Price on Chinese Stock Market

Xiao Yun,

Department of Economics
Pusan National University

2,Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan 609-735
REPUBLIC OF KOREA
a101506e@nate.com

Seong-Min Yoon

Department of Economics
Pusan National University

2,Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan 609-735
REPUBLIC OF KOREA
smyoon@pusan.ac.kr

Abstract: - Crude oil exerts a strong influence on national economy. Changes of international crude oil price have an important effect on Chinese economy because of China's high dependence on the import of the crude oil. Thus, Chinese stock market can be shocked by the fluctuation of oil price. Reversely, changes in crude oil imports of China have some effect on demands and price of the crude oil. This article will take empirical analysis on the relationship between change of international crude oil price and Chinese stock price. For this purpose, this paper builds ARMA-GARCH class models to take Granger causality test. It also tests the volatility of crude price and stock price and analyzes the relationship between them. In addition, the degree of influence will be determined by impulse response function and variance decomposition. The main results of this article are as follows: Firstly, from the results of Granger causality test, we found that comparing with the returns, the volatility of crude oil price holds more obvious influence on volatility of Chinese stock price. Especially, Brent market has stronger influence on Chinese stock market than Dubai and Minas markets. Secondly, comparing by industries, China National Petroleum Corporation (CNPC) and energy industries are shocked largely by the price fluctuation of Brent, with high risk level in market, while industries such as consumption and IT face smaller strike, with low risk level in market.

Key-Words: - Crude oil price, Chinese stock market, Granger causality test, Impulse response function, Variance decomposition.

1. Introduction

As an essential energy, crude oil is of great importance for all industries. And the changes of crude oil price can impose significant influences upon national economy through various ways. Thus it has long been the attention focus of scholars to study the influences of oil price on economy and stock market (Bernake, Gertler and Watson, 1997[1]; Sardorsky, 1999[8]; Samer, 2005[9]). Bernake, Gertler and Watson (1997) hold that the rise of international oil prices causing the authorities to adopt deflationary policies is the main reason for economic contraction. Sardorsky (1999) using the VAR model draws the conclusion that the change of international oil prices has a positive influence on the return of stock market.

And Samer (2005) proved that there existed a causal relationship between oil price and that of share, thus the rise of oil price has a negative impact on shares.

China has maintained a high speed of economic growth since the reform and opening up. The demand for crude oil, also keeps increasing. And up to now, China's crude oil external dependence has exceeded 50%, a quite high level. With the crude oil external dependence ascending, it is possible to predict the shock that the changes of international oil price bring to China's economic development and stock market. However, it is not easy to judge the degree of influence of these changes upon China's economy. In addition, since the import volume of crude oil in China is very tremendous, the volatility of China's economy may have certain affect on international

crude oil price. Nonetheless, the academic analysis on the relationship among international crude oil price, China's economy and stock market is very little, in particular, doing the analysis on the relationship on international crude oil and each industries is relatively rare. This article will focus on the empirical analysis of the relationship between international oil price and China's stock market.

Based on the import sources¹ of China's crude oil and the pricing system² of domestic petroleum products, the writer conducts the Granger causality test by using VAR model; and then impulse response function and variance decomposition are employed to observe how the influence that international crude oil prices exert on stock market will change with the passage of time. This article analyzes not only the relationship between the rate of oil price returns and the rate of stock returns, but also the relationship between the volatility of oil price and that of stock market. And then the article measures and analyzes the volatility of the two markets according to the GARCH model proposed by Bollerslev (1986)[3].

2 Literature review

As the research on the influence of international crude oil price upon stock market is a significant subject, on which many scholars have done a lot of studies. The following will focus on the previous researches on the influences that the crude oil price and its volatility impose on the stock market.

Huang, Hwang and Peng (2005)[4] indicated that the changes of crude oil price exert more notable impacts on economic activities than the volatility of crude oil price. Basher and Sadorsky (2006)[2] found that the changes of crude oil price have marked impacts on the rate of stock market return. Park and Ratti (2008) [6] reflected that while the volatility of crude oil price had a negative effect on the whole stock market, it was in a positive correlation with the rate of return of energy stocks. Sadorsky (2008)[8] drew the conclusion that medium-sized enterprises are more sensitive to the changes of oil price. Miller and Ratti (2009)[5] found that there existed a long-term negative relationship between the stock markets of the 6 countries (America, Britain, Germany, Canada, France and Italy) and crude oil prices, which means that if the oil price falls, the price of stock markets will rise. In addition, their research also shows that

this long-term relationship has disappeared since 1999. In-Cheol Kang(2012) considered that the medium-sized and small enterprises will be reacted more strongly with the volatility of crude oil price than major enterprises. And according to the classified-industries comparison, machine building industry, architecture industry and finance will quite more sensitively react to the volatility of crude oil price.

3 Data and methods

3.1. Sample data

In order to analyze the influence of crude oil prices upon Chinese market, we must know about the pricing system of China's domestic petroleum products first. Then in December 18, 2008, the National Development and Reform Commission adjusted the pricing system and figured out the price of domestic petroleum by referring to the average price of the 3 international crude oil sources: Brent, Dubai and Minas³. Moreover, the new pricing system made it a rule that in the past 22 trading days, the domestic petroleum price would be readjusted if the crude oil prices of the 3 sources rose or fell by more than 4%. Hence, it can be judged that the domestic markets in China are strongly related to the international crude oil prices in Brent, Dubai and Minas.

In terms of crude oil price, this article will employ the everyday spot price of Brent, Dubai and Minas issued by IPE and SGX as the data of international crude oil price. As for the stock markets, since Shanghai and Shenzhen are two important stock exchanges in China, this article uses the data from Shanghai composite index, Shenzhen composite index and CSI300, which can reflect the whole trend of China's stock markets, to make an analysis. At the same time, in order to make a comparison of the sensitivity among different industries, this article collects the 10 industries' sub-indices of Shanghai Stock Exchange and CSI300 respectively (including raw material, energy, industry, finance and real estate, substantial consumption, optional consumption, information technology, telecommunications service, medical treatment and public health, public utilities) and the data of the share price of China National

¹ See Table A1 in the appendix

² See the detailed description about the pricing system of China's petroleum products in the part of analytical data.

³ The concrete accounting method to determine the domestic petroleum price is through the formula: the crude oil prices in Brent, Dubai and Minas + cost + appropriate profit (providing that the average profit of the whole industry is 5% in 2004). But the National Development and Reform Commission haven't publicized the formula.

Petroleum Corporation. All the data above were analyzed between January 22, 2009 and June 30, 2014.

The crude oil price or the return rate of share prices can be worked out by difference. And the specific method of calculating the returns is shown in Eq. (1).

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (1)$$

R_t : The return rate of the respective crude oil market or stock market in the period of t.

P_t : The price of the respective crude oil market or stock market in the period of t.

P_{t-1} : The price of the respective crude oil market or stock market in the period of t-1

Table 1 is the basic statistics about the return rate of the three crude oil sources and that of the indices of China's stock markets. Then the Jarque-Bera examination is used to verify the normality of the return rate, which shows that all the data are not in the normal distribution.

Table 1. Descriptive statistics of sample returns of crude oil price and Chinese stock indices

	Sample	Mean	Median	Max	Min	Std Dev	Skewness	Kurtosis	Jarque-Bera
Brent	1228	0.000845	0.000406	0.102766	-0.088438	0.018870	0.108482	6.438190	607.26***
Dubai	1228	0.000809	0.000959	0.086753	-0.125076	0.017451	-0.172829	7.953404	1261.55***
Minas	1228	0.000768	0.000761	0.107953	-0.122516	0.018520	0.065084	6.880470	771.34***
Shanghai index	1228	0.000017	0.000326	0.059357	-0.078107	0.013846	-0.442002	5.668923	404.45***
Shenzhen index	1228	0.000474	0.001825	0.059947	-0.076582	0.016754	-0.565988	4.566350	191.10***
CSI300	1228	0.000047	0.000293	0.064619	-0.078723	0.015597	-0.341945	5.222337	276.63***
CNPC	1228	-0.000270	0.000000	0.074108	-0.078673	0.013287	0.059009	8.228927	1399.70***
Sub-indices of Shanghai Stock Exchange									
Raw material	1228	-0.000052	-0.000144	0.076449	-0.087408	0.019207	-0.215195	4.831838	181.17***
Energy	1228	-0.000249	-0.000709	0.071130	-0.094661	0.019650	-0.056985	5.054263	216.59***
Industry	1228	-0.000203	0.000347	0.061196	-0.085401	0.016003	-0.443906	5.147130	276.22***
Finance and Real Estate	1228	0.000105	-0.000379	0.076201	-0.082801	0.017346	0.013193	5.450203	307.21***
Substantial consumption	1228	0.000368	0.001030	0.059218	-0.063352	0.015932	-0.401635	4.051769	89.62***
Optional consumption	1228	0.000369	0.000980	0.058392	-0.083202	0.017286	-0.427705	4.479312	149.41***
Information Technology	1228	0.000512	0.001441	0.076468	-0.085879	0.020275	-0.446841	3.944487	86.51***
Telecommunications	1228	-0.000133	0.001106	0.075336	-0.101909	0.018650	-0.363480	4.567682	152.79***
Medical treatment	1228	0.000650	0.000752	0.068125	-0.071818	0.017164	-0.156804	4.145045	72.19***
Public utilities	1228	-0.000023	0.000145	0.047670	-0.077775	0.014529	-0.602434	5.719277	452.63***
Sub-indices of CSI300									
Raw material	1228	-0.000186	-0.000238	0.078106	-0.086749	0.019451	-0.184654	4.730758	160.25***
Energy	1228	-0.000288	-0.000642	0.075045	-0.095501	0.020072	0.015347	5.044864	214.00***
Industry	1228	-0.000191	0.000101	0.062201	-0.076668	0.016462	-0.394503	4.832722	203.71***
Finance and Real Estate	1228	0.000101	-0.000380	0.075510	-0.084663	0.017431	-0.062916	5.476245	314.55***
Substantial consumption	1228	0.000357	0.000432	0.071073	-0.061441	0.015608	-0.088922	4.127115	66.62***
Optional consumption	1228	0.000452	0.000534	0.057357	-0.079784	0.017092	-0.313235	4.392563	119.31***
Information Technology	1228	0.000269	0.001013	0.065845	-0.097791	0.020138	-0.400009	4.244009	111.93***
Telecommunications	1228	-0.000050	0.000201	0.086907	-0.099405	0.018270	-0.072720	4.892773	184.39***
Medical treatment	1228	0.000422	0.000318	0.054434	-0.069959	0.016582	-0.189006	4.100565	69.29***
Public utilities	1228	-0.000298	-0.000359	0.052660	-0.057956	0.013240	-0.342633	5.025644	233.98***

Note: *** denotes rejection of normality hypothesis at the 1% significance level.

Fig 1. Return variation of crude oil and Chinese major stock markets

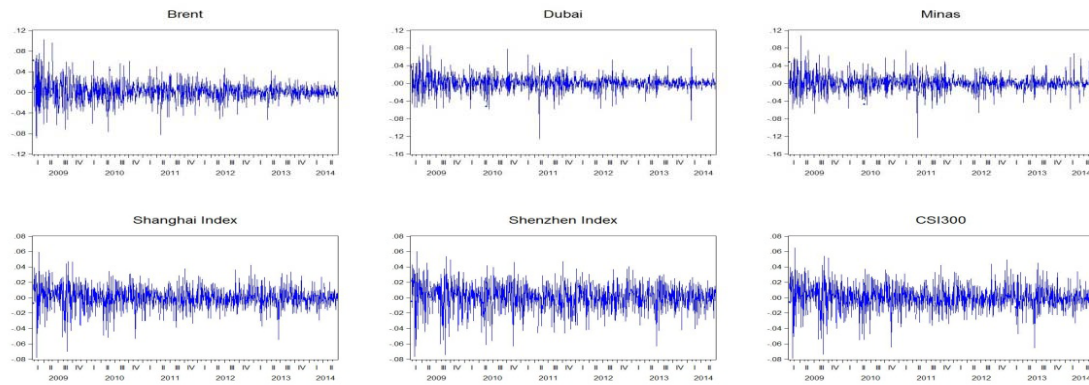


Figure 1 shows the variation trends about the return rate of the three crude oil sources (Brent, Dubai and Minas) and of the indices of the three major composite stock markets (Shanghai Stock Exchange, Shenzhen Stock Exchange and CSI300). Ever since the financial crisis in 2009, the volatility of the crude oil price or the return rate of stock markets indices, has presented a phenomenon of clustering between stationary and non-stationary stages. Therefore, the return rate of crude oil and stock markets is variable with time, that is, the return rate in a certain period will be influenced by that in the former period. This article measures the volatility of different markets by employing the GARCH model so as to reflect the temporal variability and the clustering phenomenon of the volatility of return rate more accurately.

3.2 Unit Root Test

The problem of spurious regression can easily come into being when using unstable time series data to make an analysis. Hence, it is necessary to conduct the unit root test so as to make sure the stability of validation data. The article carries out the unit root test by using the ADF verification. Moreover, whether or not there is a trend has a great influence on the results of verification, so we will differentiate two situations - with trend and no trend to conduct the verification. The result of the unit root test is shown by Table 2.

Table 2. Results of unit root test

Oil markets	ADF test statistic (No trend)	ADF test statistic (With trend)	Stock markets	ADF test statistic (No trend)	ADF test statistic (With trend)
Brent	-33.9190***	-34.0090***	Shanghai index	-34.5613***	-34.5907***
Dubai	-35.6231***	-35.7502***	Shenzhen index	-32.6424***	-32.6839***
Minas	-34.0111***	-34.1093***	CSI300	-34.4368***	-34.4783***
Sub-indices of Shanghai Stock Exchange			Sub-indices of CSI300		
Raw material	-32.5117***	-32.5776***	Raw material	-32.3925***	-32.4644***
Energy	-33.3350***	-33.4225***	Energy	-33.2026***	-33.2898***
Industry	-33.6916***	-33.7142***	Industry	-33.4704***	-33.5046***
Finance and Real Estate	-35.9738***	-35.9803***	Finance and Real Estate	-35.7706***	-35.7784***
Substantial consumption	-32.9511***	-33.0246***	Substantial consumption	-34.0656***	-34.1807***
Optional consumption	-33.2431***	-33.2974***	Optional consumption	-33.9682***	-34.0323***
Information Technology	-34.5902***	-34.5697***	Information Technology	-34.4036***	-34.3985***
Telecommunications	-33.4032***	-33.4124***	Telecommunications	-33.7994***	-33.7995***
Medical treatment	-31.7925***	-31.8477***	Medical treatment	-32.1211***	-32.1671***
Public utilities	-34.0543***	-34.0426***	Public utilities	-34.3322***	-34.3286***
Petroleum Enterprises					
CNPC	-34.7436***	-34.7562***			

Note: *** denotes rejection of unit root hypothesis at the 1% significance level.

When observing the result of unit root test, we can find that there does not exist the original assumption of unit root below the significance level of 1% whether the time series data include the trend or not. That is to say, the return rate data of the crude oil and stock markets indices don't have the unit root, and these are

stable time series data. Therefore, the following will continue conducting the empirical analysis by using the return rate of crude oil and stock markets.

3.3 Granger causality test through the VAR model

We will conduct the Granger causality test to make sure whether the changes of international oil prices lead to the changes of the return rate of China's stock markets indices or the former are caused by the latter. The Granger causality test can determine whether there exists a causal relationship between two variables by judging if one variable will be affected by the former information of another. As is shown by equations 2 and 3 of the VAR model, the article will verify if there is a causal relationship between the return rate of oil price and stock markets indices. We also investigate causality between the volatility of oil price and stock markets indices by using the VAR formula.

$$R_t = a_0 + \sum_{i=1}^m a_i R_{t-i} + \sum_{i=1}^n b_i P_{t-i} + \epsilon_t \tag{2}$$

$$P_t = c_0 + \sum_{i=1}^m c_i P_{t-i} + \sum_{i=1}^n d_i R_{t-i} + \mu_t \tag{3}$$

Here R_t stands for the return rate of different stock markets indices and P_t for the return rate of the

oil prices in Brent, Dubai and Minas. If there is at least one remarkably not being 0 among the measured values of coefficient in Eq. 2, then it can be proved that the return rate of stock markets is influenced by that of oil price. On the contrary, if the original assumption that the measured coefficient of the lag phase equals 0 is denied, then it can be stated that the return rate of stock markets will not be influenced by that of oil price. Similarly, if there is at least one measured coefficient of the lag phase not being 0, then it can be proved that the return rate of the stock markets is the cause variable of the rate of oil price return. The Akaike information criterion and Schwarz information criterion will be adopted to select appropriate lag phases when measuring the VAR model. Equations 2 and 3 above can also be used to examine the causal relationship between the volatility of the oil prices in the 3 sources and the volatility of stock market indices.

Table 3. Descriptive statistics of the measured values of the volatility

	Sample	Mean	Median	Max	Min	Std Dev	Skewness	Kurtosis	Jarque-Bera
<i>Brent</i>	1227	0.000361	0.000269	0.001728	0.000062	0.000327	2.248616	8.093713	2358.838***
<i>Dubai</i>	1227	0.000327	0.000225	0.002194	0.000057	0.000293	2.200328	9.306815	3023.619***
<i>Minas</i>	1227	0.000380	0.000293	0.002038	0.000104	0.000275	2.165535	9.500441	3119.336***
Shanghai index	1227	0.000194	0.000158	0.000550	0.000081	0.000100	1.543508	4.688081	632.8910***
Shenzhen index	1227	0.000278	0.000243	0.000892	0.000157	0.000110	2.301979	9.634406	3333.952***
CSI300	1227	0.000249	0.000215	0.000706	0.000106	0.000115	1.673852	5.501533	892.8871***
<i>CNPC</i>	1227	0.000188	0.000124	0.001011	0.000049	0.000155	2.096725	7.638044	1998.807***
Sub-indices of Shanghai Stock Exchange									
Raw material	1227	0.000369	0.000309	0.001349	0.000138	0.000211	2.007434	7.126660	1694.716***
Energy	1227	0.000389	0.000325	0.001129	0.000136	0.000192	1.254793	4.305018	409.0559***
Industry	1227	0.000255	0.000220	0.000761	0.000126	0.000109	2.124612	7.598147	2004.042***
Finance and Real Estate	1227	0.000314	0.000281	0.000839	0.000123	0.000147	1.103425	3.865978	286.5349***
Substantial consumption	1227	0.000250	0.000216	0.000811	0.000128	0.000109	2.220581	8.716136	2678.854***
Optional consumption	1227	0.000295	0.000254	0.001125	0.000153	0.000138	2.916931	13.46886	7343.135***
Information Technology	1227	0.000409	0.000357	0.001270	0.000197	0.000165	1.923184	7.250460	1680.017***
Telecommunications	1227	0.000345	0.000320	0.000875	0.000215	0.000098	1.967293	8.036902	2088.525***
Medical treatment	1227	0.000293	0.000265	0.001039	0.000158	0.000105	2.296154	10.88861	4259.712***
Public utilities	1227	0.000217	0.000168	0.000966	0.000070	0.000153	2.498204	9.628063	3522.272***
Sub-indices of CSI300									
Raw material	1227	0.000379	0.000320	0.001345	0.000142	0.000209	1.940832	6.904673	1549.792***
Energy	1227	0.000409	0.000346	0.001190	0.000129	0.000213	1.166259	4.090235	338.9207***
Industry	1227	0.000271	0.000237	0.000754	0.000131	0.000106	1.950500	6.977543	1586.851***
Finance and Real Estate	1227	0.000317	0.000284	0.000836	0.000127	0.000145	1.171621	4.002762	332.1240***
Substantial consumption	1227	0.000241	0.000217	0.000711	0.000133	0.000088	2.086276	7.987796	2161.989***

Optional consumption	1227	0.000292	0.000253	0.000998	0.000141	0.000138	2.592555	11.06020	4695.947***
Information Technology	1227	0.000402	0.000354	0.001158	0.000211	0.000160	1.940442	7.398405	1759.069***
Telecommunications	1227	0.000331	0.000317	0.000623	0.000235	0.000068	1.457475	5.748960	820.7465***
Medical treatment	1227	0.000272	0.000241	0.000830	0.000137	0.000099	2.004240	8.254243	2232.883***
Public utilities	1227	0.000176	0.000155	0.000657	0.000064	0.000089	2.382578	10.43474	3986.837***

Note: *** denotes rejection of normality hypothesis at the 1% significance level.

3.4 ARMA-GARCH model

This article will employ the GARCH model to figure out the volatility of the international crude oil markets and that of the stock markets indices. Setting ARMA (p, q) model as the average equation indicates that the variables will be influenced by the former value before the p period and that of the external variables before the q period. The variance equation will be set as GARCH (p, q). And the conditional variance during the t period will be influenced by the residual square before the p period and the conditional variance before the q period. The model will comply with the principle that coefficients should be simplest when examining the model. And the time differences of all models is 1, that is, the analysis will be conducted by setting p=1 and q=1.

The average equation and variance equation of the ARMA (1, 1)-GARCH (1, 1) model employed in the article are listed as follows:

$$r_{j,t} = a_j + \varphi_j r_{j,t-1} + \varepsilon_{j,t} + \theta_j \varepsilon_{j,t-1} \tag{4}$$

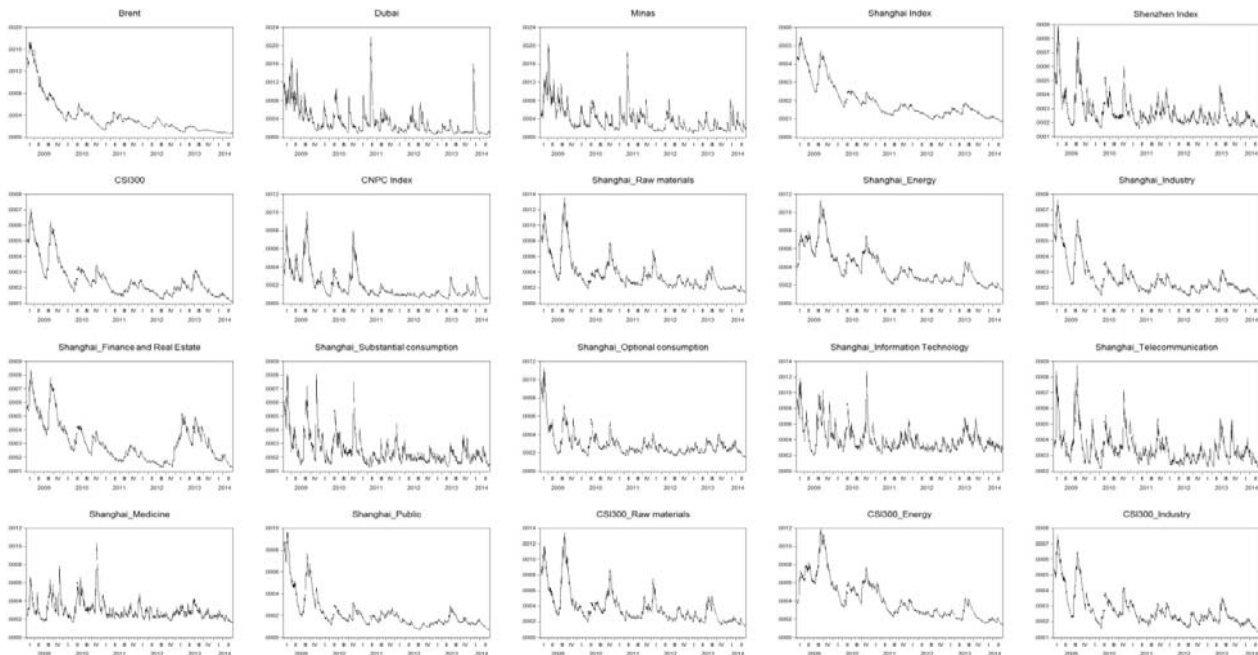
$$h_{j,t} = \alpha_j + \beta_j \varepsilon_{j,t-1}^2 + \gamma_j h_{j,t-1} \tag{5}$$

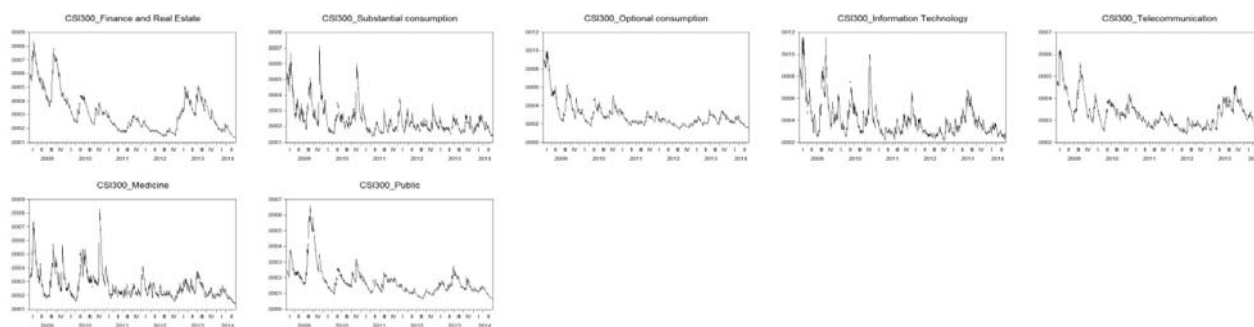
Substitute the return rate of crude oil and stock markets indices into the model and work out the value of AIC and the result is listed in Table A2 in the appendix. Table A3 is the model of the minimum value of AIC about the variables of the crude oil and stock markets indices.

The measured value of the volatility of crude oil and stock markets can be figured out through the above model. Table 3 shows the basic statistics of the measured values of the volatility that have been worked out.

Figure 2 reflects the variation trend of the volatility of the crude oil markets and that of the stock markets during analytical period.

Fig 2. Volatility variation of crude oil and Chinese stock markets





4 Empirical analysis

4.1 Results of Granger causality test

To judge what relationship between international crude oil market and China's stock markets, the following Granger causality test of the rate of returns and volatility between these two kinds of markets respectively will be carried out. And determine the lag phase through the minimum principle of AIC and SIC. The original assumption is that "the volatility of crude oil price(stock market price) is not the cause variable of the volatility of stock market price(crude oil price)". If the value of the statistical magnitude F worked out is bigger than the critical value, then the original assumption will be denied. Table 4 is the result of Granger causality test between the return rate of the crude oil markets in Brent, Dubai and Minas and that of China's stock markets indices.

As is shown in the table 4, under the significance level of 10%, the return rate of Brent has certain effect on the finance and real estate industries. And in addition to this condition, the original assumption that the causal relationship does not exist cannot be denied. Therefore, among the stock markets indices analyzed in this article, the return rate of international crude oil price is not the causal variable of the return rate of China's stock markets. However, regard to that the impact of China's stock market on international crude oil price, the return rate of raw material index has a certain effect on the return rate of Brent and Dubai. And the return rate of energy and industry will exert a influence on the return rate of Dubai crude oil price. In addition to these conditions, other original assumption that the causal relationship does not exist cannot be rejected.

Table 4. Results of Granger causality test between the returns of crude oil and stock markets

Returns of stock markets	Crude oil markets → Stock markets. F-Statistic(Prob)			Stock markets → Crude oil markets. F-Statistic(Prob)		
	Brent	Dubai	Minas	Brent	Dubai	Minas
Shanghai index	1.8562(0.1733)	0.0367(0.8484)	0.1098(0.7405)	0.2138(0.6439)	1.9937(0.1582)	0.4328(0.5108)
Shenzhen index	0.7162(0.3944)	0.0002(0.9903)	0.2873(0.5921)	0.8744(0.3499)	2.2222(0.1363)	0.7719(0.3798)
CSI300	1.7162(0.1904)	0.0180(0.8934)	0.4204(0.5169)	0.3241(0.5693)	2.6098(0.1065)	0.7542(0.3853)
CNPC	0.7858(0.3755)	0.9672(0.3256)	0.4389(0.5078)	0.0021(0.9638)	0.7881(0.3749)	0.0041(0.9491)
Sub-indices of Shanghai Stock Exchange						
Raw material	0.0853(0.7703)	0.2218(0.6378)	1.0829(0.2983)	3.0695(0.0800)*	2.7813(0.0956)*	0.9149(0.3390)
Energy	0.2931(0.5883)	0.0815(0.7753)	0.3772(0.5392)	0.8451(0.3581)	2.8616(0.0910)*	0.4552(0.5000)
Industry	1.1000(0.2945)	0.0660(0.7974)	0.0755(0.7836)	0.0032(0.9552)	3.1929(0.0742)*	1.3231(0.2503)
Finance and Real Estate	3.0940(0.0788)*	0.1086(0.7419)	0.4087(0.5227)	0.0370(0.8475)	1.6252(0.2026)	0.3892(0.5328)
Substantial consumption	2.4768(0.1158)	0.8179(0.3660)	0.1149(0.7347)	0.1935(0.6601)	1.9978(0.1578)	0.3676(0.5444)
Optional consumption	0.8246(0.3640)	0.1131(0.7367)	0.1930(0.6605)	0.4726(0.4919)	1.2938(0.2556)	0.6117(0.4343)
Information Technology	0.6445(0.4222)	0.6493(0.4205)	0.0071(0.9329)	0.7234(0.3952)	0.9507(0.3297)	0.1987(0.6659)
Telecommunications	0.2035(0.6520)	0.0000(0.9956)	0.0700(0.7914)	0.0537(0.8168)	1.0420(0.3076)	0.0301(0.8623)
Medical treatment	2.2524(0.1337)	0.3742(0.5409)	0.0364(0.8487)	0.0994(0.9054)	0.7054(0.4011)	0.1430(0.7054)
Public utilities	2.4781(0.1157)	0.4725(0.4920)	0.0119(0.9131)	0.1698(0.6803)	1.1472(0.2844)	0.3728(0.5416)
Sub-indices of CSI300						
Raw material	0.1063(0.7444)	0.1355(0.7129)	0.8637(0.3529)	2.7194(0.0994)*	3.1413(0.0766)*	1.1025(0.2939)
Energy	0.1582(0.6909)	0.1924(0.6610)	0.4890(0.4845)	0.7440(0.3886)	3.0843(0.0793)*	0.5531(0.4572)
Industry	0.6329(0.4265)	0.0141(0.9056)	0.1835(0.6684)	0.0210(0.8847)	2.8234(0.0932)*	1.2198(0.2696)
Finance and Real Estate	3.2244(0.0728)*	0.0792(0.7784)	0.3369(0.5617)	0.5841(0.5578)	1.7016(0.1923)	0.4177(0.5182)
Substantial consumption	1.4552(0.2279)	0.1577(0.6914)	0.0358(0.8500)	0.0800(0.7773)	1.6670(0.1969)	0.4020(0.5262)
Optional consumption	1.0698(0.3012)	0.0006(0.9805)	0.3008(0.5835)	0.1153(0.7343)	1.4000(0.2370)	0.6179(0.4320)
Information Technology	1.1827(0.2770)	0.8268(0.3634)	0.0163(0.8984)	1.5819(0.2087)	0.8015(0.3708)	0.1240(0.7248)
Telecommunications	0.0079(0.9290)	0.3320(0.5646)	0.6860(0.4077)	0.0001(0.9909)	0.8871(0.3465)	0.0070(0.9334)
Medical treatment	2.0334(0.1313)	0.1244(0.7244)	0.0114(0.9150)	0.1995(0.6552)	0.7318(0.3925)	0.0223(0.8814)
Public utilities	2.1506(0.1428)	0.7627(0.3827)	0.0189(0.8906)	0.0409(0.8397)	1.7275(0.1890)	0.9056(0.3415)

Note: * denote rejection of null hypothesis that there is no Granger causality at the 10% significance levels.

Table 5 is the result of Granger causality test between the volatility of the crude oil markets in Brent, Dubai and Minas and that of China's stock markets indices. Except CSI-300-raw material, all of other volatility of stock market index will be affected by the volatility of Brent crude oil price. However, the fluctuation of Dubai and Minas will only impact the fluctuation of energy industry, while other industries except for energy will not be influenced by the fluctuation of Dubai and Minas.

Regarding to the impact of the volatility of China's stock market on international crude oil price, the results shows that, the fluctuation of Shanghai composite index, CSI300 index, CNPC, and the industries like industry, substantial consumption, optional consumption will exert the impact on Brent, Dubai and Minas.

Through the Granger causality test, we can find that, compared with the rate of return, there exists a more remarkable causal relationship between the volatility of crude oil price and that of stock markets. That is to say, the volatility of crude oil price and

stock markets indices is more persuasive than the rate of return among the studies about the influences that crude oil price imposes on China's stock markets. Besides, according to the price of Brent, Dubai and Minas, the volatility of Brent crude oil price imposes more influences on China's stock market than the other two crude oil prices. And the volatility of Brent not only has affect on the crude oil price sensitive industries, but also imposes impact on respective stock composite index and the majority of industries. On the contrary, the fluctuation of Dubai and Minas will only have influence on energy industry. However, concerning the impact of stock market on crude oil market, three oil markets will all be influenced by the China's stock market, and the indices like Shanghai composite index, CSI300 and industry will all impose affect on three crude oil market.

Table 5. Results of Granger causality test between the volatility of crude oil and stock markets

Returns of stock markets	Crude oil markets → Stock markets. F-Statistic(Prob)			Stock markets → Crude oil markets. F-Statistic(Prob)		
	Brent	Dubai	Minas	Brent	Dubai	Minas
Shanghai index	4.945(0.026)**	0.033(0.855)	0.063(0.802)	7.410(0.007)***	9.679(0.002)***	6.667(0.010)***
Shenzhen index	8.227(0.004)***	0.322(0.571)	0.694(0.405)	0.795(0.373)	5.242(0.022)**	2.602(0.107)
CSI300	5.591(0.018)**	0.115(0.735)	0.034(0.854)	4.757(0.029)**	7.210(0.007)***	5.055(0.025)**
CNPC	4.785(0.029)**	1.406(0.236)	1.294(0.256)	2.967(0.086)*	5.541(0.019)**	4.229(0.040)**
Sub-indices of Shanghai Stock Exchange						
Raw material	3.288(0.070)*	0.309(0.578)	0.438(0.508)	2.730(0.099)*	4.924(0.027)**	2.485(0.115)
Energy	12.230(0.001)***	4.379(0.037)**	4.622(0.032)**	0.551(0.458)	4.831(0.028)**	1.290(0.256)
Industry	5.431(0.020)**	0.015(0.904)	0.017(0.897)	8.401(0.004)***	10.045(0.002)***	7.283(0.007)***
Finance and Real Estate	4.347(0.037)**	0.450(0.502)	0.065(0.799)	1.426(0.233)	3.651(0.056)*	3.319(0.069)*
Substantial consumption	7.066(0.008)***	0.211(0.646)	0.670(0.413)	4.139(0.042)**	5.735(0.017)**	3.043(0.081)**
Optional consumption	4.602(0.032)**	0.003(0.956)	0.121(0.728)	18.370(0.000)***	9.765(0.002)***	8.221(0.004)***
Information Technology	3.750(0.053)*	0.079(0.778)	0.149(0.699)	1.896(0.169)	4.990(0.026)**	3.749(0.053)**
Telecommunications	5.907(0.015)**	0.958(0.328)	0.637(0.425)	0.518(0.472)	2.674(0.102)	2.072(0.150)
Medical treatment	3.727(0.054)*	0.119(0.730)	0.044(0.834)	0.038(0.846)	3.536(0.060)*	1.965(0.161)
Public utilities	2.845(0.092)*	0.081(0.777)	0.013(0.911)	16.094(0.000)***	10.372(0.001)***	8.899(0.003)***
Sub-indices of CSI300						
Raw material	2.560(0.109)	0.248(0.619)	0.171(0.680)	3.786(0.052)*	4.125(0.043)**	2.434(0.119)
Energy	13.520(0.000)***	5.866(0.016)**	5.938(0.015)**	0.523(0.470)	4.941(0.026)**	1.277(0.259)
Industry	6.033(0.014)**	0.060(0.807)	0.052(0.821)	5.903(0.015)**	8.830(0.003)***	6.321(0.012)**
Finance and Real Estate	4.259(0.039)**	0.385(0.535)	0.038(0.845)	1.589(0.208)	3.616(0.057)*	3.223(0.073)*
Substantial consumption	7.135(0.008)***	0.484(0.487)	0.386(0.535)	6.271(0.012)**	4.312(0.038)**	4.715(0.030)**
Optional consumption	3.598(0.058)*	0.000(0.997)	0.000(0.997)	21.037(0.000)***	10.866(0.001)***	10.292(0.001)***
Information Technology	3.390(0.066)*	0.003(0.959)	0.004(0.951)	2.081(0.149)	3.861(0.055)*	2.570(0.109)
Telecommunications	3.164(0.076)*	0.081(0.777)	0.022(0.882)	3.339(0.068)*	4.224(0.040)**	3.214(0.073)*
Medical treatment	5.027(0.025)**	0.092(0.761)	0.005(0.941)	0.413(0.521)	4.224(0.040)**	3.356(0.067)*
Public utilities	3.246(0.072)*	0.461(0.498)	0.634(0.426)	0.517(0.473)	3.451(0.064)*	1.823(0.177)

Note: ***, ** and * denote rejection of null hypothesis that there is no Granger causality at the 1%, 5% and 10% significance levels, respectively.

4.2 Results of impulse response function and variance decomposition

Figure 3 is the impulse response function of the stock markets indices with changes of Brent crude oil

price measured through the VAR model. Along with the impulse of Brent crude oil, the response of Shanghai composite Index, CSI300 and industry

indices such as raw material, energy, industry, finance and real estate, substantial consumption, optional consumption, medical treatment and public health react gradually increase to the fluctuation of Brent crude oil, taking on spillover effect, about 30-60 days later, the degree of response reaches to its utmost, and then the response of the volatility of this above indices begins to decrease, presenting the convergence effect. Nevertheless, faced with the impulse of the volatility of Brent crude oil, the response of the share prices of Shenzhen composite index, CNPC and Shanghai Stock Exchange-telecommunication service,

etc. takes on the monotone decreasing convergence effect at the very beginning.

Figure 4 is the impulse response function of the energy stock markets indices with the fluctuation of the crude oil price of Dubai and Minas. Faced with the impulse of the volatility of the crude oil in Dubai and Minas, the response of energy stock market indices gradually increases firstly, and about 30 days later, the degree of response reaches to its utmost and then decrease.

Fig 3. Impulse response of Chinese stock market to Brent crude oil market

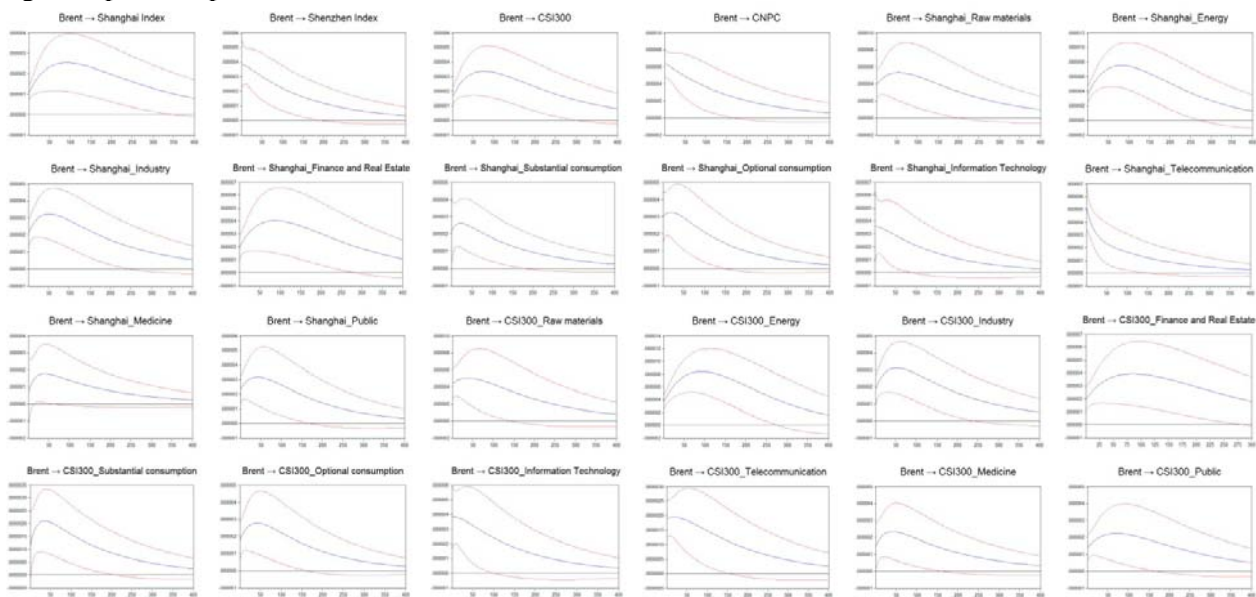


Fig 4. Impulse response of Chinese stock market to crude oil market of Dubai and Minas

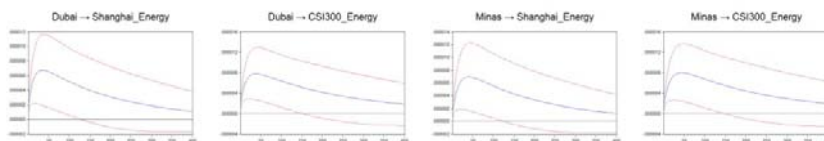


Fig 5 Impulse response of Brent crude oil price to Chinese stock market

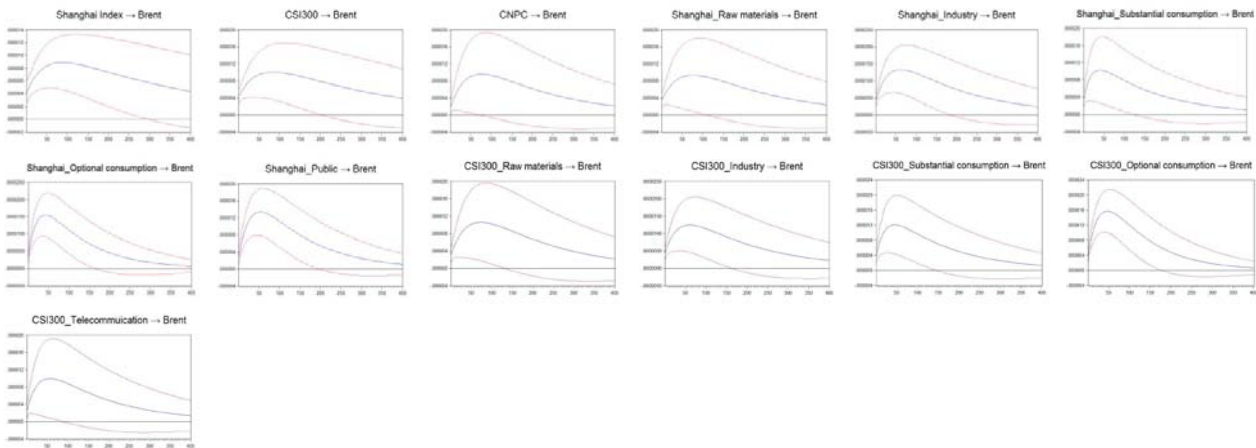


Figure 5 and Figure 6 shows the impulse response function of the Brent and Minas crude oil price with the change of China's stock market. Accompany with the impulse of Shanghai composite Index, the response of CSI300, CNPC and other industry indices like industry will augment firstly, and after 30-60 days, the degree of response arrives at its maximum, and then appear gradually decrease. Figure 7 is the impulse response function of Dubai crude oil price along with the fluctuation of China's

stock market. Except Shanghai composite Index, faced with other impulse of industry indices, the response of Dubai crude oil increase firstly, and about 20 days later, the degree of response reaches to its utmost and then decrease gradually. That is to say that, the response reaction of Dubai crude oil price will be faster than other two crude oil markets(Brent and Minas).

Fig 6 Impulse response of Minas crude oil price to Chinese stock market

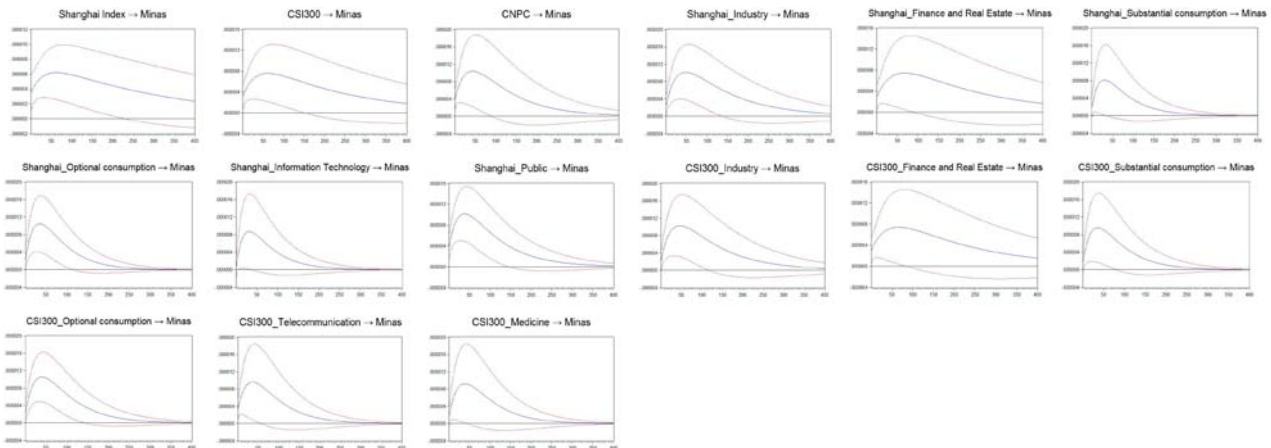
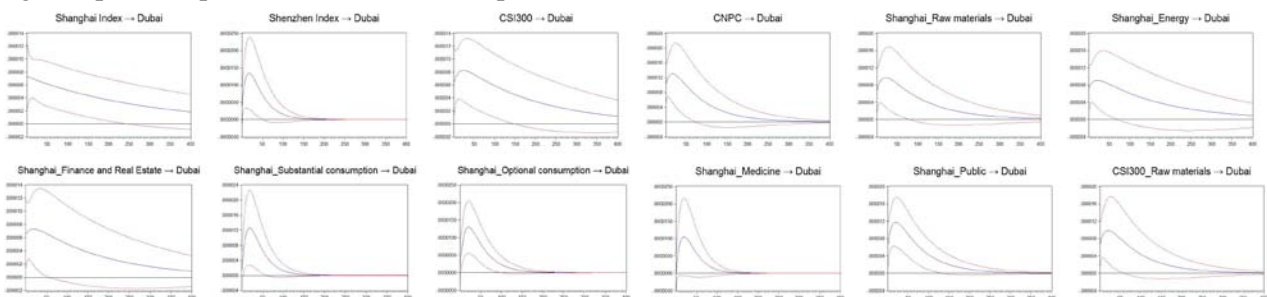


Fig 7 Impulse response of Dubai crude oil price to Chinese stock market



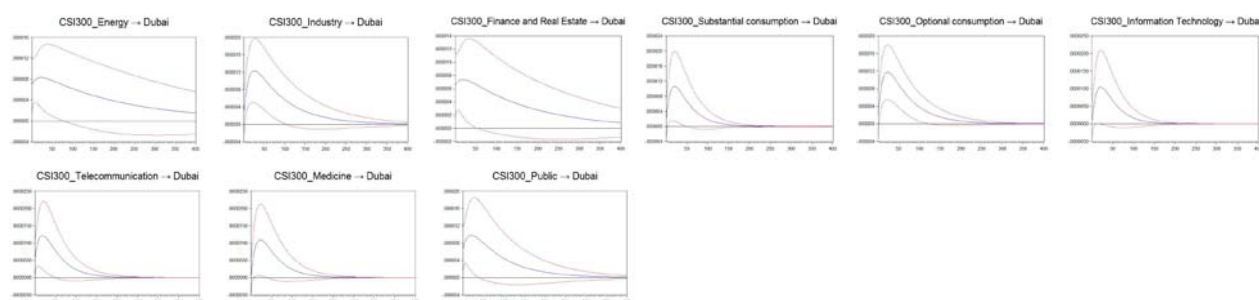


Table 7 is the result of the variance decomposition. With time passing, the parts of the stock markets indices that can be illustrated according to the volatility of international crude oil are increasing gradually. Compared with the crude oil in Dubai and Minas, the parts of the stock markets indices that can be illustrated according to the volatility of international crude oil are bigger. The influence of Brent crude oil upon China's stock markets is widespread and significant; and the crude in Dubai and Minas just has a relatively remarkable influence on industries (companies) sensitive to oil price. In the 3 composite indices, the indices of sensitivity to Brent

crude oil, from high to low, are Shanghai composite index, Hushen300 index and Shenzhen composite index. The greater the changes of international oil prices are, the higher the investment of Shanghai Stock Exchange risks. In terms of result of the variance decomposition of the sectors (companies) indices, the part of energy, industry, finance and real estate etc. that can be illustrated according to Brent crude oil exceeds 20%, while the substantial consumption, medical treatment and public health and information technology that can be illustrated by crude oil is less than 10%.

Table 7. Variance decomposition of the volatility of stock markets

Variance decomposition of stock markets		Lag					
		50	100	150	200	250	300
Composite stock markets	Shanghai index	87.43	77.18	69.73	64.94	61.98	60.18
	Brent	12.57	22.82	30.27	35.06	38.02	39.82
	CSI300	89.19	79.96	73.35	69.28	66.90	65.53
	Brent	10.81	20.04	26.65	30.72	33.10	34.47
	Shenzhen index	92.74	89.26	87.50	86.59	86.11	85.87
	Brent	7.26	10.74	12.50	13.41	13.89	14.13
Petroleum Enterprises	CNPC	90.07	86.11	83.91	82.72	82.09	81.74
	Brent	9.93	13.89	16.09	17.28	17.91	18.26
Sub-indices of Shanghai Stock Exchange	Energy	85.84	73.59	64.87	59.83	57.21	55.94
	Brent	14.16	26.41	35.13	40.17	42.79	44.06
	Industry	89.28	82.12	77.86	75.52	74.26	73.56
	Brent	10.72	17.88	22.14	24.48	25.74	26.44
	Finance and Real Estate	93.34	87.20	82.05	78.46	76.19	74.83
	Brent	6.66	12.80	17.95	21.54	23.81	25.17
	Raw material	94.00	89.72	86.66	84.78	83.70	83.08
	Brent	6.00	10.28	13.34	15.22	16.30	16.92
	Public utilities	93.10	88.93	86.53	85.30	84.69	84.39
	Brent	6.90	11.07	13.47	14.70	15.31	15.61
	Optional consumption	94.35	91.40	89.99	89.34	89.04	88.90
	Brent	5.65	8.60	10.01	10.66	10.96	11.10
Telecommunications	93.21	91.18	90.13	89.57	89.27	89.11	
Brent	6.79	8.82	9.87	10.43	10.73	10.89	
Substantial consumption	96.30	93.97	92.77	92.15	91.82	91.65	
Brent	3.70	6.03	7.23	7.85	8.18	8.35	
Information Technology	97.46	96.11	94.41	95.05	94.87	94.77	
Brent	2.54	3.89	4.59	4.95	5.13	5.23	
Medical treatment	98.77	97.60	96.94	96.58	96.38	96.27	
Brent	1.23	2.40	3.06	3.42	3.62	3.73	
Sub-indices of CSI300	Energy	85.42	72.65	63.17	57.44	54.34	52.97
	Brent	14.58	27.35	36.83	42.56	45.66	47.21
	Finance and Real Estate	93.35	87.26	82.19	78.67	76.46	75.13
	Brent	6.65	12.74	17.81	21.33	23.54	24.87
	Industry	91.25	84.54	80.46	78.22	77.00	76.33
Brent	8.75	15.46	19.54	21.78	23.00	23.67	

Telecommunications	93.38	89.95	87.80	86.58	85.92	85.56
Brent	6.62	10.05	12.20	13.42	14.08	14.44
Public utilities	95.96	92.61	89.86	87.98	86.82	86.13
Brent	4.04	7.39	10.14	12.02	13.18	13.87
Raw material	94.83	91.72	89.60	88.35	87.64	87.25
Brent	5.17	8.28	10.40	11.65	12.36	12.75
Optional consumption	94.90	91.30	89.36	88.43	87.98	87.78
Brent	5.10	8.70	10.64	11.57	12.02	12.22
Substantial consumption	96.33	93.32	91.71	90.86	90.41	90.17
Brent	3.67	6.68	8.29	9.14	9.59	9.83
Medical treatment	97.03	94.45	92.91	92.07	91.60	91.35
Brent	2.97	5.55	7.09	7.93	8.40	8.65
Information Technology	96.44	94.54	93.53	93.01	92.74	92.59
Brent	3.56	5.46	6.47	6.99	7.26	7.41
Shanghai-Energy	88.83	86.74	86.07	85.78	85.64	85.56
Dubai	11.17	13.36	13.93	14.22	14.36	14.44
CSI300- Energy	86.28	83.75	82.91	82.52	82.32	82.20
Dubai	13.62	16.25	17.09	17.48	17.68	17.80
Shanghai-Energy	88.76	85.90	84.96	84.55	84.33	84.22
Minas	11.24	14.10	15.04	15.45	15.67	15.78
CSI300- Energy	86.36	82.81	81.62	81.08	80.80	80.63
Minas	13.64	17.19	18.38	18.92	19.20	19.37

Table 8 and Table 9 shows the variance decomposition of Brent and Minas. Similar with the variance decomposition of stock market, with the time passing, the variance of respective crude oil market that can be elucidated by the fluctuation of stock market are gradually increasing. The industries of China's stock market which imposes relatively strong impulse to the Brent crude oil market are as follows: CSI300-optional consumption, Shanghai stock market-industry, Shanghai stock market-public utilities, Shanghai stock market-optional consumption etc. The variance decomposition result of Minas is

similar with Brent. The industries of China's stock market which brings to bear relatively intensively impulse to the Minas crude oil market are as follows: Shanghai stock market-industry, CSI300-industry, Shanghai stock market-public utilities, CSI300-optional consumption, CNPC, CSI300 etc. Table 10 shows the variance decomposition of Dubai crude oil price. The industries of China's stock market which inflict on relatively mightily impulse to the Dubai crude oil market are as follows: Shanghai stock market-industry, CSI300-industry, CNPC etc.

Table 8. Variance decomposition of the volatility of Brent crude oil market

Variance decomposition of stock markets	Lag					
	50	100	150	200	250	300
Brent	70.76	57.37	52.88	51.32	50.76	50.56
CSI300-Optional consumption	29.24	42.63	47.12	48.68	49.24	49.44
Brent	80.91	69.18	63.55	60.81	59.41	58.66
Shanghai-Industry	19.09	30.82	36.45	39.19	40.59	41.34
Brent	79.38	66.94	61.96	59.92	58.06	58.68
Shanghai-Public utilities	20.62	33.06	38.04	40.08	40.94	41.32
Brent	73.62	63.83	60.80	59.75	59.36	59.21
Shanghai-Optional consumption	26.38	36.17	39.20	40.25	40.64	40.79
Brent	90.28	81.41	74.63	69.95	66.74	64.51
Shanghai composite index	9.72	18.59	25.37	30.05	33.26	35.49
Brent	84.14	74.85	70.40	68.24	67.13	66.54
CSI300-Industry	15.86	25.15	29.60	31.76	32.87	33.46
Brent	89.69	81.19	75.21	71.35	68.89	67.29
CSI300	10.31	18.81	24.79	28.65	31.11	32.71
Brent	90.56	83.08	78.69	76.29	75.00	74.29
CSI300-Raw material	9.44	16.92	21.31	23.71	25.00	25.71
Brent	84.66	78.83	76.74	75.88	75.48	75.29
CSI300-Substantial consumption	15.34	21.17	23.26	24.12	24.52	24.71
Brent	92.18	86.27	82.55	80.38	79.13	78.40
Shanghai-Raw material	7.82	13.73	17.45	19.62	20.87	21.60
Brent	93.08	87.05	83.51	81.57	80.51	79.93
CNPC	6.92	12.95	16.49	18.43	19.49	20.07
Brent	90.96	85.94	83.75	82.75	82.28	82.04
CSI300-Telecommunication	9.04	14.06	16.25	17.25	17.72	17.96
Brent	88.55	85.04	83.86	83.37	83.14	83.03
Shanghai-Substantial consumption	11.45	14.96	16.14	16.63	16.86	16.97

Table 9. Variance decomposition of the volatility of Minas crude oil market

Variance decomposition of stock markets	Lag					
	50	100	150	200	250	300
Minas	89.67	81.16	77.35	75.78	75.13	74.86
Shanghai-Industry	10.33	18.84	22.65	24.22	24.87	25.14
Minas	89.98	82.15	78.93	77.72	77.28	77.12
CSI300-Industry	10.02	17.85	21.07	22.28	22.72	22.88
Minas	88.08	81.06	78.68	77.95	77.74	77.67
Shanghai-Public utilities	11.92	18.94	21.32	22.05	22.26	22.33
Minas	88.36	80.74	78.46	77.90	77.77	77.74
CSI300-Optional consumption	11.64	19.26	21.54	22.10	22.23	22.26
Minas	89.56	82.56	79.73	78.73	78.39	78.28
CNPC	10.44	17.44	20.27	21.27	21.61	21.72
Minas	94.25	88.24	84.17	81.70	80.23	79.34
CSI300	5.75	11.76	15.83	18.30	19.77	20.66
Minas	95.29	89.89	85.95	83.53	82.09	81.24
Shanghai-Finance and real estate	4.71	10.11	14.05	16.47	17.91	18.76
Minas	95.38	90.61	86.97	84.43	82.67	81.43
Shanghai composite index	4.62	9.39	13.03	15.57	17.33	18.57
Minas	95.28	89.98	86.18	83.88	82.55	81.78
CSI300-Finance and real estate	4.72	10.02	13.82	16.12	17.45	18.22
Minas	89.10	83.87	82.68	82.46	82.42	82.41
Shanghai-Optional consumption	10.90	16.13	17.32	17.54	17.58	17.59
Minas	91.36	87.19	86.06	85.81	85.76	85.75
CSI300-Telecommunication	8.64	12.81	13.94	14.19	14.24	14.25
Minas	91.54	87.44	86.44	86.23	86.18	86.18
CSI300-Substantial consumption	8.46	12.56	13.56	13.77	13.82	13.82
Minas	92.56	88.34	87.16	86.90	86.85	86.83
CSI300-Medical treatment	7.44	11.66	12.84	13.10	13.15	13.17
Minas	93.34	90.92	90.45	90.37	90.35	90.35
Shanghai-Information technology	6.66	9.08	9.55	9.63	9.65	9.65
Minas	93.83	91.68	91.24	91.15	91.14	91.14
Shanghai-Substantial consumption	6.17	8.32	8.76	8.85	8.86	8.86

Table 10. Variance decomposition of the volatility of Dubai crude oil market

Variance decomposition of stock markets	Lag					
	50	100	150	200	250	300
Dubai	90.75	86.02	84.49	83.97	83.79	83.73
Shanghai-Industry	9.25	13.98	15.51	16.03	16.21	16.27
Dubai	90.65	86.36	85.22	84.91	84.82	84.80
CSI300-Industry	9.35	13.64	14.78	15.09	15.18	15.20
Dubai	89.48	86.09	85.27	85.07	85.02	85.00
CNPC	10.52	13.91	14.73	14.93	14.98	15.00
Dubai	90.47	87.35	86.68	86.54	86.51	86.50
Shanghai-Public utilities	9.53	12.65	13.32	13.46	13.49	13.50
Dubai	95.17	91.91	89.99	88.84	88.14	87.71
CSI300-Energy	4.83	8.09	10.01	11.16	11.86	12.29
Dubai	94.41	91.05	89.33	88.44	87.97	87.72
Shanghai-Energy	5.59	8.95	10.67	11.56	12.03	12.28
Dubai	94.89	91.50	89.60	88.53	87.91	87.55
CSI300	5.11	8.50	10.40	11.47	12.09	12.45
Dubai	91.27	88.35	87.86	87.78	87.77	87.77
CSI300-Optional consumption	8.73	11.65	12.14	12.22	12.23	12.23
Dubai	90.55	88.73	88.60	88.59	88.59	88.59
Shanghai-Optional consumption	9.45	11.27	11.40	11.41	11.41	11.41
Dubai	96.00	93.36	91.57	90.35	89.50	88.90
Shanghai composite index	4.00	6.64	8.43	9.65	10.50	11.10
Dubai	93.71	90.66	89.58	89.19	89.05	89.00
Shanghai-Raw material	6.29	9.34	10.42	10.81	10.95	11.00
Dubai	93.81	91.26	90.54	90.35	90.29	90.27
CSI300-Raw material	6.19	8.74	9.45	9.65	9.71	9.73
Dubai	91.48	90.46	90.41	90.41	90.41	90.41
Shenzhen composite index	8.52	9.54	9.59	9.59	9.59	9.59
Dubai	92.10	90.56	90.44	90.43	90.43	90.43
CSI300-Telecommunication	7.90	9.44	9.56	9.57	9.57	9.57
Dubai	94.05	91.52	90.80	90.60	90.54	90.53
CSI300-Public utilities	5.95	8.48	9.20	9.40	9.46	9.47
Dubai	96.22	93.82	92.51	91.78	91.37	91.14
Shanghai-Finance and real estate	3.78	6.18	7.49	8.22	8.63	8.86

Dubai	96.17	93.78	92.50	91.81	91.44	91.23
CSI300-Finance and real estate	3.83	6.22	7.50	8.19	8.56	8.77
Dubai	92.49	91.61	91.59	91.59	91.59	91.59
Shanghai-Substantial consumption	7.51	8.39	8.41	8.41	8.41	8.41
Dubai	94.00	92.46	92.33	92.32	92.31	92.31
CSI300-Medical treatment	6.00	7.54	7.67	7.68	7.69	7.69
Dubai	93.46	92.74	92.72	92.72	92.72	92.72
Shanghai-Information technology	6.54	7.26	7.28	7.28	7.28	7.28
Dubai	94.20	93.11	93.04	93.04	93.04	93.04
CSI300-Substantial consumption	5.80	6.89	6.96	6.96	6.96	6.96
Dubai	94.20	93.11	93.66	93.66	93.66	93.66
CSI300-Information technology	5.29	6.28	6.34	6.34	6.34	6.34
Dubai	95.04	94.38	94.36	94.36	94.36	94.36
Shanghai-Medical treatment	4.96	5.62	5.64	5.64	5.64	5.64

We drew the conclusion that Brent crude oil exerted a stronger and more widespread influence upon China's stock markets than the crude oil in Dubai and Minas by establishing the VAR model analysis.⁴ Table A1 listed the original source and proportion of China's crude oil.

Although the import from the Middle East is the most, the crude oil imported from Africa, South America, Russia, Central Asia, Australia etc. is calculated according to the price of Brent crude oil;⁵ meanwhile, Brent has a strong influence in the Middle East. And since Brent crude oil price has significant influence on Central Asia. Hence, it can be induced that there are close correlation between Brent crude oil price and China's market.

5 Conclusions

This article analyzed the interaction effect between international crude oil prices and China's stock markets by employing the international crude oil prices in Brent, Dubai and Minas and the indices of China's stock markets from January 22, 2009 to June 30, 2014. The indices include Shanghai composite index, Shenzhen composite, CSI300, etc. and the sub-indices of the 10 industries of Shanghai Stock Exchange and CSI 300 respectively and the data of CNPC's share prices. The main conclusions are as follows:

First, through the Granger causality test, we can find that, compared with the rate of return, there exists a more remarkable causal relationship between the volatility of crude oil price and that of stock markets; the volatility of crude oil price and stock markets indices is more persuasive than the rate of return. Second, among Brent, Dubai and Minas, the volatility of Brent crude oil price has remarkable

affect on the majority of China's stock market indices, while the fluctuation of Dubai and Minas only has significant influence on energy industry. Besides, according to the impulse response function and variance decomposition analysis, the indices of China's stock markets have more extensive response to the changes of Brent crude oil. That is to say, compared with Dubai and Minas, the crude oil in Brent imposes a more remarkable influence on China's stock markets. Third, the response of Shanghai composite index is more sensitive to the volatility of Brent crude oil, while the response of Shenzhen composite index is relatively insensitive. As for the sectors, industries sensitive to oil prices, such as energy, manufacturing and CNPC, present a bigger response and their market risk is relatively high; industries insensitive to oil price, such as substantial consumption, information technology, etc. present a smaller response and their market risk is relatively low. Fourth, Brent, Dubai and Minas can be all imposed impulse by the China's stock market, and according to the variance decomposition, China's stock market industries such as industry and optional consumption will impose strong impulse to international stock market.

Although there are significant correlations between international crude oil price and China's stock market, the interaction speed of the two markets is relatively low. No matter what aspect of influence there is, the influence of international crude oil price on China's stock market or the impact of China's stock market on international crude oil, the degree of reaction reaches its maximum value about 20-30 days later. The reason why this kind of phenomenon happened with high possibility is that because of the pricing system of China's domestic petroleum. In the past 22 trading days, the domestic petroleum products price was readjusted when the variation amount of the crude oil prices in the 3 sources (Brent, Dubai and Minas) exceeded more than 4%. Therefore, the domestic markets haven't been integrated with the international crude oil markets completely, thus domestic market responds slowly to the impulse from the international crude oil markets. The system

⁴ For the information of import sources of China's crude oil and the proportion, see Table A1 in the appendix.

⁵ The National Development and Reform Commission made it a rule that the crude oil imported from Africa, South America, Russia, Central Asia, Australia, etc. should be calculated according to the price of Brent crude oil.

hinders the integration of domestic markets into the international crude oil markets and goes against guaranteeing the profit of petroleum enterprises. There have been voices for reforming the pricing system of petroleum products since 2013. And there is also news claiming that the National Development and Reform Commission is considering shortening the 22 pricing days into 10 days and cancel the limitation of the variation amount exceeding more than 4%. Hence, it is necessary to pay constant attention to the development trend of China's domestic crude oil markets.

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Appendix

Table A1. The import sources of China's crude oil and the proportion

Rank	Country	Rank	Country	Rank	Country
1	SAUDI ARABIA(18.67%)	8	KAZAKHSTAN(4.20%)	15	YEMEN(1.68%)
2	ANGOLA(16.46%)	9	KUWAIT(4.11%)	16	AUSTRALIA(1.20%)
3	IRAN(8.91%)	10	BRAZIL(3.36%)	17	MALAYSIA(0.87%)
4	OMAN(6.63%)	11	VENEZUELA(3.15%)	18	COLOMBIA(0.84%)
5	RUSSIA(6.37%)	12	LIBYA(3.08%)	19	ALGERIA(0.73%)
6	SUDAN(5.26%)	13	UAE(2.21%)	20	INDONESIA(0.58%)
7	IRAQ(4.70%)	14	CONGO(2.11%)		
Middle East(45.21%), Africa(29.61%), South America(8.16%), Southeast Asia(2.26%)					

Table A2. Finding optimal specification of ARMA-GARCH model (values of AIC)

		Model			
		GARCH(1,1)	AR(1)-GARCH(1,1)	MA(1)-GARCH(1,1)	ARMA(1,1)-GARCH(1,1)
Crude oil markets	<i>Brent</i>	-5.3685	-5.3670	-5.3671	-5.3668
	<i>Dubai</i>	-5.4450	-5.4453	-5.4439	-5.4442
	<i>Minas</i>	-5.2655	-5.2642	-5.2653	-5.2638
Composite stock markets	Shanghai index	-5.8182	-5.8200	-5.8166	-5.8184
	Shenzhen index	-5.4009	-5.4043	-5.4025	-5.4031
	CSI300	-5.6102	-5.6106	-5.6086	-5.6090
Sub-indices of Shanghai Stock Exchange	Raw material	-5.1782	-5.1813	-5.1795	-5.1799
	Energy	-5.1111	-5.1133	-5.1109	-5.1122
	Industry	-5.4936	-5.4963	-5.4933	-5.4947
	Finance and Real Estate	-5.3587	-5.3587	-5.3581	-5.3594
	Substantial consumption	-5.5108	-5.5148	-5.5135	-5.5132
	Optional consumption	-5.3508	-5.3528	-5.3507	-5.3514
	Information Technology	-5.0192	-5.0202	-5.0188	-5.0187
	Telecommunications	-5.1576	-5.1563	-5.1562	-5.1597
	Medical treatment	-5.3548	-5.3631	-5.3637	-5.3626
	Public utilities	-5.8092	-5.8093	-5.8079	-5.8078

	Raw material	-5.1457	-5.1486	-5.1470	-5.1472
	Energy	-5.0795	-5.0815	-5.0795	-5.0807
	Industry	-5.4685	-5.4702	-5.4685	-5.4687
	Finance and Real Estate	-5.3439	-5.3461	-5.3432	-5.3446
Sub-indices of CSI300	Substantial consumption	-5.5316	-5.5326	-5.5310	-5.5310
	Optional consumption	-5.3696	-5.3704	-5.3682	-5.3689
	Information Technology	-5.0322	-5.0334	-5.0313	-5.0320
	Telecommunications	-5.1832	-5.1808	-5.1821	-5.1817
	Medical treatment	-5.4250	-5.4314	-5.4312	-5.4314
	Public utilities	-5.9391	-5.9386	-5.9375	-5.9468

Table A3. Selection of estimation model

Stock markets	Model	Stock markets	Model
Crude oil markets		Composite stock markets	
<i>Brent</i>	GARCH(1,1)	Shanghai index	AR(1)-GARCH(1,1)
<i>Dubai</i>	AR(1)-GARCH(1,1)	Shenzhen index	AR(1)-GARCH(1,1)
<i>Minas</i>	GARCH(1,1)	CSI300	AR(1)-GARCH(1,1)
Sub-indices of Shanghai Stock Exchange		Sub-indices of CSI300	
Raw material	AR(1)-GARCH(1,1)	Raw material	AR(1)-GARCH(1,1)
Energy	AR(1)-GARCH(1,1)	Energy	AR(1)-GARCH(1,1)
Industry	AR(1)-GARCH(1,1)	Industry	AR(1)-GARCH(1,1)
Finance and Real Estate	AR(1)-GARCH(1,1)	Finance and Real Estate	AR(1)-GARCH(1,1)
Substantial consumption	AR(1)-GARCH(1,1)	Substantial consumption	AR(1)-GARCH(1,1)
Optional consumption	AR(1)-GARCH(1,1)	Optional consumption	AR(1)-GARCH(1,1)
Information Technology	ARMA(1,1)-GARCH(1,1)	Information Technology	GARCH(1,1)
Telecommunications Service	AR(1)-GARCH(1,1)	Telecommunications Service	AR(1)-GARCH(1,1)
Medical treatment	MA(1)-GARCH(1,1)	Medical treatment	AR(1)-GARCH(1,1)
Public utilities	AR(1)-GARCH(1,1)	Public utilities	ARMA(1,1)-GARCH(1,1)
Petroleum Enterprises			
<i>CNPC</i>	ARMA(1,1)-GARCH(1,1)		