Analysis of the information transmission between Chinese and international oil markets

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Abstract: In recent years, the continuous increase in oil demands and the high dependence on imported oil in China have led to a closer relationship between Chinese and international oil markets. Moreover, the influence of Chinese oil markets is increasing because of tremendous development in its futures market for fuel oil. This paper investigates the different impacts of the Daqing crude oil spot market and the Shanghai fuel oil futures market on international oil markets using error correction model and variance decomposition. The results indicate that the Chinese oil markets are cointegrated with international oil markets. The Daqing crude oil spot market is the price taker and is significantly influenced by international oil markets. However, the Shanghai fuel oil futures market has had competitive advantage compared with the Singapore fuel oil market and a strong effect on the long-term price volatility of international oil markets.

Keywords: China's oil markets; International oil markets; Information transmission; ECM

1. Introduction

Since China became a net importer of oil in 1993 and of crude oil in 1996, oil imports have continuously increased. In 2010, total crude oil imports reached 239 million tons, with a year-on-year growth of 17.5%, and dependence on oil imports reached 53.8%. China's oil markets and international oil markets have become increasingly close. Since 1998, an oil pricing mechanism has gradually been established in China whereby price changes are integrated with the international oil price, and price comovement between China and international oil markets has strengthened. As oil marketization has progressed, oil prices in China have been increasingly affected by international oil prices (Jiao et al., 2007).

Chinese oil production reached 203 million tons in 2010, ranking fifth in the world. Oil consumption was 428.6 million tons, accounting for 10.6% of world oil consumption and ranking second. Oil imports reached 294.5 million tons, ranked second in the world (BP, 2011). In particular, after the 2008 global financial crisis, OECD countries, especially the USA, experienced severe economic recession and weak oil demands, so increasing oil demands in developing countries such as China have played a major role in supporting the international oil price. In 2010, the growth rate for world oil consumption was 3.1%, whereas the rate for China reached 10.4%, which represents a 32.1% contribution to the world increase (BP, 2011). The great oil demand in

China is thought to be an important factor in boosting the recovery of the international oil price and Chinese markets have had a tremendous influence on international oil markets.

In addition, fuel oil futures, the only oil futures contract so far in China was launched on the Shanghai Futures Exchange in 2004 and provided a basis for the development strategy for Chinese oil marketization. Shanghai fuel oil futures have rapidly developed and are now the third largest energy futures in the global market. The market trading volume is just behind WTI and Brent and its influence is continuously increasing. This provides a good explanation of the transformation of the world oil trading situation under current economic conditions and the influence of Asian oil consumers, especially China’s have the say on the international oil market. Because of this situation, an understanding of the relationship between Chinese and international oil markets and an analysis of the influence of Chinese oil markets on the international market would be beneficial for the Chinese market system and for competition in international oil markets.

Owing to relatively late development and the low level of marketization, the literature on Chinese oil markets is still limited. Zhang et al. (2007) investigate the volatility characteristics of the Chinese Daqing crude oil price using GARCH models based on a generalized error distribution. The results reveal that the leverage effect of Chinese oil price volatility is significant, with a 1.7-fold asymmetric impact of price decreases relative to price increases. Cong et al. (2008) investigate the relationships between Chinese oil price shocks and the stock market using a multivariate vector auto-regression model. The results reveal that the impact of oil price shocks on the manufacturing index is significant. Dai and Zhou (2009) investigate the dynamic relationship among oil price volatility, volume and open interest using a GARCH model and an impulse response function. The results indicate that volume plays an important role in explaining volatility and can be used to forecast future volatility. Wang et al. (2011) study the price duration features of the Chinese fuel oil futures market. The results show that price duration has an obvious intraday effect and that trading volume and open interest volume are crucial factors affecting fluctuations in price duration. Li and Lin (2011) investigate the changing structure of the world oil price system by identifying an emerging-market factor as additional driver using cointegration and an error correction model (ECM). The results indicate that demand from Chinese markets has become a significant factor in the world oil pricing system since 2003. Conclusions about the relationship between Chinese and international oil markets are basically consistent: the impact of international price on the Chinese price is rapid and dramatic, whereas the reverse impact is relatively slow and weak (Jiao et al., 2007, Chen et al., 2009).

This paper focuses on Chinese oil markets and chooses the Daqing crude oil spot market and Shanghai fuel oil futures market as representatives of two different market types for analysis. These markets are also used for a comparison of the characteristics of information transmission to and from international oil markets and an evaluation of the influence of Chinese oil markets. The main contributions of the paper are as follows. (1) We investigate the long-run equilibrium relationship between Chinese and international oil markets using an ECM. (2) The impacts of Chinese oil markets are explored using forecast error variance decomposition with a contemporaneous restriction provided by the directed acyclic graph method.

2. Model for information transmission among oil markets

To better understand the interaction between Chinese and international oil markets, we analyze the information transmission mechanism among them using an ECM with forecast error variance decomposition.

Let X_t denote a vector including Chinese and international oil prices. Assuming that oil price series are integrated of the same order (test details are in Section 4.1), the corresponding ECM is specified as follows:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \varepsilon_t \qquad (t = 1, 2, \ldots, T) \tag{1}$$

where Δ is the difference operator ($\Delta X_t = X_t - X_{t-1}$). Π is a coefficient matrix $\Pi = \alpha\beta'$, where β is the cointegrating vector and α indicates the speed of adjustment to the previous period's deviation from the cointegrating relationship. Γ_i is a matrix of short-run coefficients, μ is a vector of intercepts, and ε_t is a vector of deviations.

The Johansen Trace test and Maximum Eigenvalue test (Johansen and Juselius, 1990) are used to determine cointegrating rank. The test statistics are specified as follows:

$$Trace = -T \sum_{i=r+1}^{k} \ln(1 - \lambda_i) \tag{2}$$

$$\lambda_{\max} = -T \ln(1 - \lambda_{r+1}) \tag{3}$$

Where λ_i is eigenvalues, T is the number of observations, while r is the maximum number of cointegrating vectors.

In general, the commonly used Granger test can only identify lag causality and does not explain contemporaneous causal relations. Therefore, variance decomposition of ECM (Sims, 1980) is used to explore the dynamic structure. To illustrate the short-run dynamic structure, we rewrite $\triangle X_t$ of Equation (1) as an infinite moving average process:

$$\Delta X_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}, \quad t = 1, 2, \ldots, T \tag{4}$$

The error from the forecast of $\triangle X_t$ at the n-step-ahead horizon, conditional on information available at t–1 is:

$$\xi_{t,n} = \sum_{l=0}^{n} A_l \varepsilon_{t+n-l} \tag{5}$$

Correspondingly, the variance-covariance matrix of the total forecasting error is:

$$\mathrm{cov}(\xi_{t,n}) = \sum_{l=0}^{n} A_l \mathrm{H} A_l^{'} \tag{6}$$

Where H is the variance-covariance matrix of ε_t. The early research was used to adopt the Cholesky factorization which later variables cannot cause contemporaneous changes in the previous variables. This assumption has a great influence on variance decomposition due to ordering of the variables (Swanson and Granger, 1997). Therefore, the directed acyclic graph technique (for more details, readers are referred to Sprites et al., 2000) is used to overcome the unrealistic assumption in the Cholesky decomposition.

3. Sample analysis for oil markets

To investigate the influence of Chinese oil markets on international oil markets, prices of crude oil and fuel oil are taken as representatives. The Daqing oil field is the largest in China and its crude oil output accounts for approximately 25% of national production. Since its price basically represents the level of crude oil prices in China, we choose Daqing crude oil spot prices as representative of the Chinese crude oil price (CCO) (there is no crude oil futures market in China). The fuel oil futures prices on the Shanghai Futures Exchange are selected as Chinese fuel oil prices (CFO). In international oil markets, WTI crude oil futures prices (WTI), US fuel oil futures prices (UFO) from the New York Mercantile Exchange (NYMEX) and Singapore 180CST fuel oil prices (SFO) are chosen for comparison. Weekly data over the period from 22 October

2004 to 19 August 2011 (352 observations) are selected according to availability; CCO and WTI data are obtained from the Energy Information Administration (EIA), while CFO, UFO and SFO data are from the Mytrader database.

The summary of statistics for logarithm returns for Chinese and international oil markets is presented in Table 1. The results reveal that long-term returns for Chinese and international oil markets show almost no difference, at approximately 0.002. The standard deviations show that the Chinese oil markets behave much steadier than that of international oil markets. Moreover, because Daqing crude oil spot prices follow the international pricing system, fluctuations are close to those of the international oil market. Shanghai fuel oil futures exhibit the lowest volatility, reflecting the effect of Chinese policy adjustments and control on the futures market. However, the Chinese fuel oil futures market is not fully open and speculation is weak relative to international oil markets. All the returns exhibit a non-normal distribution as verified by the Jarque-Bera test. Correlation between Chinese and international oil markets remains high. In addition, Daqing crude oil prices follow WTI prices closely, and thus match the international pricing system. In addition, correlation between Shanghai and Singapore fuel oil prices is comparatively high and the two markets influence each other greatly.

Table 1. Descriptive Statistics for Weekly Log Returns for Oil Market[a] (2004.10—2011.8)

Oil Markets	Symbol	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
WTI	WTI	0.002	0.048	-0.773	8.198	430.058**[b]
NYMEX fuel oil	UFO	0.002	0.047	-0.361	4.133	26.398**
Singapore fuel oil	SFO	0.003	0.049	-0.286	6.048	140.694**
Shanghai fuel oil	CFO	0.002	0.035	-0.168	7.673	320.960**
Daqing crude oil	CCO	0.002	0.046	-0.824	6.464	215.157**

Correlation

	WTI	UFO	SFO	CFO	CCO
WTI	1				
UFO	0.981	1			
SFO	0.956	0.923	1		
CFO	0.853	0.775	0.914	1	
CCO	0.983	0.974	0.959	0.832	1

Notes: [a] Returns for oil prices are calculated as 100*ln ($price_t/price_{t-1}$).

[b] * and ** denote significance at the 5% and 1% levels, respectively.

Table 2 shows the Granger causality results between Chinese oil markets and international oil markets. International fuel oil market can granger cause WTI, which indicates that refinery product prices have great influence on crude oil prices. This implies that oil price trends have mainly been driven by demand in recent years (supported by Hamilton, 2009). The other four oil markets of WTI, UFO, SFO and CFO can granger cause CCO, which indicates that China's crude oil market is a price taker with respect to the other markets. This performance may be related to the lack of crude oil futures market in China and the insensitivity of the crude oil spot market to price changes. On the contrary, Chinese fuel oil futures traded on the Shanghai Futures Exchange can rapidly respond to international price changes because of the relatively open market characteristic. Therefore, Chinese fuel oil futures prices provide orientation for Chinese crude oil spot prices. In addition, Chinese fuel oil market granger causes Singapore fuel oil market. It reveals that because of the high degree of marketization and the increasing volume, Chinese fuel oil futures market is strong enough to compete with the Singapore market and its leading role in price changes has enhanced.

Table 2. Granger Causality Test between Oil Markets

	2004.10—2011.8			
Lag order	1	2	3	4
Null Hypothesis		F-Stat		
UFO/→ WTI	3.74*	21.77**	15.76**	11.99**
WTI/→ CCO	8.69**	68.50**	49.23**	36.25**
UFO/→ CCO	39.22**	184.83**	130.23**	97.96**
SFO/→ CCO	13.24**	68.30**	45.79**	34.62**
CFO/→ CCO	10.04**	32.41**	23.29**	17.05**
CCO/→ UFO	5.10*	4.53*	5.74**	4.24**
CFO/→ SFO	5.84*	4.29*	3.24*	2.45*

Note: The Granger causalities between Chinese oil (including crude oil and fuel oil) and international oil prices are tested. /→ denotes there is not Granger causality from the left market to the right. * and ** denote significance at the 5% and 1% levels, respectively. Without loss of generality, the number of lags is selected from 1 to 4, where the results are presented in Table 2 only if the entire four lagged tests are significant.

4. Empirical analysis of the impact of Chinese oil markets

4.1 Unit root and cointegration tests

An augmented Dickey-Fuller and Phillips-Perron test are applied as the unit root test for each variable. From Table 3, all the variables are integrated of order one, *I*(1). We construct a VAR model for Chinese and international oil markets; the optimal number of lags is 2 using the Schwarz information criterion. The Johansen cointegration results (Johansen and Juselius, 1990) in Table 3 suggest that five cointegrating vectors exist. Thus, an error correction model for oil markets is constructed.

Table 3. Unit Root and Cointegration Tests

Variable	Unit Root Test		Cointegration Test			
	ADF t-Statistic	Phillips-Perron t-Statistic	Hypothesized No. of CE(s)	Trace Statistic	C(5%)[a]	D[b]
WTI	-1.90	-2.41	None*	122.35	79.34	**R**
△WTI	-18.24**	-18.58**				
UFO	-1.77	-2.09	At most 1*	78.60	55.25	**R**
△UFO	-18.29**	-18.40**				
SFO	-1.83	-2.53	At most 2*	38.65	35.01	**R**
△SFO	-16.92**	-17.51**				
CFO	-2.48	-3.06	At most 3*	19.57	18.40	**R**
△CFO	-17.20**	-17.45**				
CCO	-1.98	-2.22	At most 4*	6.99	3.84	**R**
△CCO	-13.65**	-13.90**				

Note: * and ** denote significance at the 5% and 1% levels, respectively. [a]. the number of cointegrating vector is test using the trace test with the trend and intercept terms. C(5%) denote critical value of trace test at 5% significant level. [b]. "D" gives decision to reject(R) or fail to reject (F) at 5% significant level.

4.2 Contribution of Chinese oil markets to international oil markets

We construct the ECM for Chinese and international oil markets and the correlation matrix of innovation in equation (1) is estimated. Then the variables order can be restricted using directed acyclic graph method (Awokuse and Bessler, 2003; Bessler and Yang, 2003) and forecast error variance decomposition is conducted. The percentage of forecast error variance is shown at 1-week, 12-week and 48-week level.

The variance decomposition results for oil markets are presented in Table 4. In general, the influence of international oil markets lasts in the short time, whereas Chinese oil markets make a great contribution in the long term. This indicates that the large Chinese demand for oil supports world oil prices in the long run. Specifically, the percentage contribution of WTI to its own price volatility decreases with time and is 81.57%, 60.37% and 44.77% at 1-week, 12-week and 48-week level, respectively. The contribution of NYMEX fuel oil to WTI price volatility remains relatively steady at approximately 19%. Chinese oil markets make a great contribution to WTI in the long term and the percentage contribution of Daqing crude oil and Shanghai fuel oil prices together reaches 32.21%. Price volatility for NYMEX fuel oil can be explained by itself most of time, with a percentage contribution of more than 60% in the long run, while the contribution of the Shanghai fuel oil market is 17.98%. For the Singapore fuel oil market, its own percentage contribution to price volatility is no more than 50% at 1-week level and that of the NYMEX and Shanghai fuel oil markets together is 45.76% and increases with time to 73.59% in the long run (48 weeks). In addition, the Daqing crude oil market contributes to price fluctuations in the Singapore market, amounting to over 10% in the long run.

Table 4. Variance Decomposition for the Contemporaneous Structure in Figure 1

Step	WTI	UFO	SFO	CFO	CCO
			(WTI)		
1	81.57	18.43	0.00	0.00	0.00
12	60.37	19.55	1.59	7.43	11.06
48	44.77	19.39	3.62	10.94	21.27
			(UFO)		
1	0.00	100	0.00	0.00	0.00
12	4.44	83.88	1.58	1.85	8.25
48	10.91	60.60	3.76	17.98	6.75
			(SFO)		
1	4.66	27.50	49.59	18.26	0.00
12	12.92	38.56	11.20	25.60	11.72
48	9.07	45.84	4.95	27.75	12.38
			(CFO)		
1	0.00	0.00	0.00	100.00	0.00
12	3.73	7.62	5.55	82.93	0.18
48	4.63	10.51	8.42	62.12	4.31
			(CCO)		
1	6.33	15.46	0.26	6.23	71.72
12	2.37	21.35	0.54	8.99	66.76
48	2.72	40.53	2.45	30.59	23.71

Notes: Variance decompositions are given based on the contemporaneous causality relationship as in Figure 1.

International oil markets have little influence on the Shanghai fuel oil market but have strong impact on the Daqing crude oil market. Price volatility for Shanghai fuel oil futures is mainly explained by itself and the percentage contribution reaches more than 60% in the long term. This indicates that Chinese futures markets are not completely open and the government plays the main role in influencing market fluctuations. For the Daqing crude oil market, its own percentage contribution to price volatility decreases from 71.27% at 1-week level to 23.71% at 48-week level. In the long run, the percentage contribution of the NYMEX and Shanghai fuel oil markets to the volatility of Daqing crude oil market is 40.53% and 30.59%, respectively.

5. Conclusions

This study reveals a long-term equilibrium relationship between Chinese and international oil markets using an ECM. The impact of the Daqing crude oil and Shanghai fuel oil markets on international oil markets is analyzed by identifying information transmission among them. Some important conclusions for Chinese oil markets can be drawn.

First, with the stronger degree of marketization, the relationship between Chinese and international oil markets has become much closer. In particular, there is a long-term equilibrium relationship between Chinese and international oil markets.

Second, The Daqing crude oil market is a price taker and affected by international oil markets and the Shanghai fuel oil market. In addition, we find that Chinese oil markets make a great contribution to the price volatility of international oil markets in the long term and the position of Chinese oil markets is continuously promoted.

Finally, government regulations still play an important role in Chinese oil markets. Under this situation, oil market behavior is subject to some restrictions and Chinese oil markets cannot exert its full effect.

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References

Awokuse, T.O., Bessler, D.A., 2003. Vector autoregression, policy analysis, and directed graphs: an application to the US economy. Journal of Applied Economics, 6, 1-24.

Bessler, D.A., Yang, J., 2003. The structure of interdependence in international stock markets. Journal of International Money and Finance, 22(2), 261-287.

BP, 2011. BP statistical review of the world energy. BP, London.

Chen, K.C., Chen, S.L., Wu, L.F., 2009. Price causal relations between China and the world oil markets. Global Finance Journal, 20(2), 107-118.

Cong, R.G., Wei, Y.M., Jiao, J.L., Fan, Y., 2008. Relationships between oil price shocks and stock market: an empirical analysis from China. Energy Policy, 36, 3544-3553.

Dai, Y., Zhou, D.Q., 2009. Relations among volume, open interest and volatility in fuel oil futures market. Systems Engineering Theory & Practice, 29(12), 154-162 (In Chinese).

Hamilton, J., 2009. Causes and consequences of the oil shock of 2007-2008. Brookings Papers on Economic Activity, 215-261.

Jiao, J.L., Fan, Y., Wei, Y.M., Han, Z.Y., Zhang, J.T., 2007. Analysis of the co-movement between chinese and international crude oil price. International Journal of Global Energy Issues, 27(1), 61-76.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration-with application to the demand for money. Oxford Bulletin of Economics and Statistics, 52, 169-210.

Li, H., Lin, X.W., 2011. Do emerging markets matter in the world oil pricing system? Evidence of imported crude by China and India. Energy Policy, 39, 4624-4630.

Sims, C., 1980. Macroeconomics and Reality. Econometrica, 48, 1-48.

Sprites, P., Glymour, C., Scheines, R., 2000. Causation, prediction, and search. Cambridge: MIT Press, 1-130.

Swanson, N., Granger, C., 1997. Impulse response functions based on a causal approach to residual Orthogonalization in Vector Autoregression. Journal of the American Statistical Association, 92, 357-367.

Wang, F., Liu, C.Z., Wang, Y., 2011. Study on the price duration features and determinants of china's Fuel oil futures market based on microstructure theory. Energy Procedia, 5, 219-223.

Zhang, Y.J., Fan, Y., Wei, Y.M., 2007. Study on the characteristics of Chinese crude oil price volatility based on GED-GARCH models. Application of Statistics and Management, 26(3), 398-406 (In Chinese).