Oil Price and Exchange Rate of China
——A Nonlinear Granger Approach

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Abstract. We investigate the possible nonlinear causality relationships between crude oil price and RMB exchange rate which usually ignored by previous researches which are mainly focused on the traditional linear side. As shown in many researches recently, the nonlinear structure of energy price has been widely considered. To fill this gap, we employ nonlinear causality test to examine the Granger relationships between the above two series. Our results indicate that there exists the unidirectional nonlinear causality running from to crude oil price to RMB exchange rate from July 2005 to March 2013.

Introduction

Oil is a kind of nonrenewable strategic resource with an ever significant importance for today's economy. Over the past three decades, both the price and world demand of oil flare up generally with the world economic development. Thanks to the pioneering work of Hamilton (1983) who laid down the interrelations between oil price and economic fundamentals, on this basis, numerous academic researches have been conducted to investigate the linkages between them. As a leading variable of economic fundamentals, the existing literatures paid much attention on the mixed relations of exchange rate and oil price. The main research prospects are as follows:

Since the RMB exchange rate system reform 2005, which changed China's traditional fixed exchange rate system into the well-managed floating exchange rate system with reference to a basket of currencies. The reform make renminbi depegged from dollar and set a very narrow floating band, therefore the RMB exchange rate could volatile with different driving forces. Since China's exchange rate system reform, renminbi has appreciated about 24.40%, while the world crude oil price rising from U.S. $56.41 per barrel at the beginning of July 1st 2005 to U.S. $108.46 per barrel on March 28th 2013. The growing prices of crude oil may influence the emerging economy, especially the developing countries like China, who has a great need for oil. From the year 2006 to 2011, the oil demand of China flares up sharply, with limited oil supply domestically, China has to depend on oil imports. In the end of 2011, oil import dependence of China was up to 55.91%, China has been listed as the second-largest oil importer globally, next only to the United States. "Is there any nexus of renminbi exchange rate and oil price?" "Who dominates who?" etc., are important areas needed exploration.

However, the existing literatures have three limitations. First, the causality relationship tests are limited to examine oil price and economic fundamentals of China other than renminbi exchange rate.(See, e.g., Cong and Wei (2008) for study on oil price shocks and Chinese stock market; Du and He (2010) for research on the world oil price and economic growth and inflation of China). Second, previous studies are generally conducted on the basis of traditional Granger (1969) causality test. Third, recent researches supposed that the structure of oil price movement tend to be nonlinear (See, e.g., Arouri and Jawadi (2010) for reveal the strong nonlinear relationship between crude oil and exchange rates ; Wang and Wu (2012) for examine the nonlinear causality relation between energy price and exchange rates).

Therefore, the objective of this paper focused on the nonlinear causality relationship between oil price and renminbi exchange rate with experience learned from previous studies. The rest of this paper is organized as follows. In the next section, we discuss the methodology issues. In section 3, we provide the data description and some data issues. Section 4 present the empirical results and relevant analysis. Finally, we conclude the main findings and policy implications.

Empirical Methodology

The traditional linear Granger causality test has reached the matured status and become a useful economic tool. Until recently, Hiemstra and Jones (1994) proposed a nonparametric test (HJ test) for nonlinear Granger type relation, which is widely used in testing two stationary series under joint cumulative distribution. However, Diks and Panchenko (2005) found that this traditional approach has a vital defect in detecting the nonlinear causality relations and may cause over rejections of null hypothesis. The reason is that the HJ test ignores the possible variation under null hypothesis with the appropriate bandwidth condition. In order to remedy these shortcomings, Diks and Panchenko (2006) developed a new test statistics to detect the probable nonlinear Granger relationship. The hypothesis and test process are given by:

$$H_0 : Y_{t+1} \mid (X_t^{l_x}; Y_t^{l_y}) \sim Y_{t+1} \mid Y_t^{l_y} \qquad (1)$$

Where $\{x_t\}$ is a strictly Granger cause of $\{y_t\}$ (t≥1), and "~" denotes the equivalence in distribution. Besides, $X_t^{l_x}$ and $Y_t^{l_y}$ are delay vectors, where $X_t^{l_x}=(X_{t-l_x+1},\cdots,X_t)$ and $Y_t^{l_y}=(X_{t-l_y+1},\cdots,Y_t)$ $(l_x, l_y \geq 1)$. The null hypothesis H_0 is that the past observations of $X_t^{l_x}$ contains no useful information of Y_{t+1}, as described in equation (1). And then we take the dimensional vector $W_t=(X_t,Y_t,Z_t)$ to conclude the invariant distribution of (l_x+l_y+1), Where $Z_t=Y_{t+1}$. Under the previous research, we usually drop the time index and write the dimensional vector as $W=(X,Y,Z)$ to denote $W_t=(X_t,Y_t,Y_{t+1})$ and in this paper we only discuss the condition when $l_x=l_y=1$. Thus, the conditional distribution of Z given by (X,Y)=(x,y) is the same as that of Z given by Y=y, so we can conclude the relationship equation between joint probability density function and its marginal probability density function as follows:

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(\mathrm{y})} = \frac{f_{X,Y}(x,y)}{f_Y(\mathrm{y})} \cdot \frac{f_{Y,Z}(y,z)}{f_Y(\mathrm{y})} \qquad (2)$$

Equation (2) implies that X and Z are independent conditionally on Y. According to Diks and Panchenko (2006)'s work, the null hypothesis implies the following equation:

$$\mathrm{q_g} = \mathrm{E}\Big[\Big(\frac{f_{X,Y,Z}(x,y,z)}{f_Y(\mathrm{y})} - \frac{f_{X,Y}(x,y)}{f_Y(\mathrm{y})} \cdot \frac{f_{Y,Z}(y,z)}{f_Y(\mathrm{y})}\Big) \cdot \mathrm{g}(X,Y,Z)\Big]=0 \qquad (3)$$

where $\mathrm{g}(X,Y,Z)$ is the positive weight function. Diks and Panchenko (2006) had considered several possible choice of the weight function g, and here we choose the option of $\mathrm{g}(X,Y,Z)$, we then refer to the corresponding function as q:

$$q = E[\mathrm{f}_{X,Y,Z}(x,y,z)\mathrm{f}_Y(y) - \mathrm{f}_{X,Y}(x,y)\mathrm{f}_{Y,Z}(y,z)] \qquad (4)$$

and a natural estimator function of q is:

$$T_n(\varepsilon) = \frac{(2\varepsilon)^{-dx-2dy-dz}}{n(n-1)(n-2)} \sum_i \Big[\sum_{k\neq i}\sum_{j\neq i}(I_{ik}^{XYZ} I_{ij}^{Y} - I_{ik}^{XY} I_{ij}^{YZ})\Big] \qquad (5)$$

where $I_{ij}^W = I(\|W_i - W_j\| < \varepsilon)$, I(·) is the indicator function and ε is the bandwidth. Then we can simplify $T_n(\varepsilon)$ by introducing the density estimator of d_w – variate random vector W at W_i by

$$\hat{f}_w(\mathrm{w}_i) = \frac{(2\varepsilon)^{-dw}}{n-1} \sum_{j,j\neq i} I_{ij}^w \quad \text{into:}$$

$$T_n(\varepsilon) = \frac{(n-1)}{n(n-2)} \sum_i [\hat{f}_{X,Y,Z}(x_i,\mathrm{y}_i,\mathrm{z}_i)\,\hat{f}_Y(\mathrm{y}_i) - \hat{f}_{X,Y}(x_i,\mathrm{y}_i)\,\hat{f}_{Y,Z}(\mathrm{y}_i,\mathrm{z}_i)] \qquad (6)$$

Diks and Panchenko (2006) finally proved that $T_n(\varepsilon)$ follows the distribution:

$$\sqrt{n}\,\frac{T_n(\varepsilon)-q}{S_n}\xrightarrow{D}N(0,1) \qquad (7)$$

where " $\xrightarrow{D}$ " means the convergence in distribution and S_n denotes the asymptotic variance of $T_n(\cdot)$. Based on the above work of Diks and Panchenko (2006) we can test the nonlinarity between oil price and EX rate of Chinese market.

Data

Interdependence of oil price and renminbi exchange rate was investigated by monthly data from July 2005 to March 2013. We employ crude oil price in U.S dollar per barrel for West Texas Intermediate (WTI) benchmark, given that WTI is closely linked to other main crude oil markers worldwide as well as an important determination of other U.S light crudes (See, Reboredo, 2011). As WTI oil price is dollar-denominated spot nominal price, we deflate it by CPI. The exchange rate (Renminbi per unit of U.S dollar) data referred to real effective exchange rate (REER) index, which not only consider the currencies and trade weights of major trading partners change, but also eliminates the inflation factor, can more accurately reflect the external value of the currency of a country. The WTI oil price is derived from Energy Information Administration (EIA) and real effective exchange rate data from Bank for International Settlements (BIS). Fig. 2 illustrates the co-movements of China's BIS exchange rate and crude oil price over the whole period, which indicates almost matching fluctuations trend in crude oil and renminbi exchange rate: they tend to oscillate in opposite direction, both the oil price and REER rising up steadily, especially the crude oil price, reaching the peak of 141.06 dollars per barrel in July 2008. However, under the attack of 2008 financial crisis oil price dived to about 40 dollars per barrel in March 2009 and later increased up slowing with slight oscillations. At the same time, renminbi REER almost appreciated continuously in later month except Nov. 2008 to Dec. 2009.

Fig. 2 WTI crude oil price and real effective exchange rate index for the period July 2005 to March 2013

Empirical results

Unit Root Test. Prior to nonlinear causality analysis, we need conduct unit root test to assure the stationarity of oil price as well as EX rate of RMB. Table 1 reports the results of unit root test based on ADF and the optimal lag lengths of ADF test are decided by Schwarz information criterion (SIC). From the table we can find that oil price is stationary at 10% level while the RMB exchange rate is non-stationary. And the first difference of both oil price and exchange rate series are stationary at 1% significant level, they are obey the behavior of Ⅰ(1) process.

Table.1 Result of the Unit Root Test

Variable	（C,T,N）	Z Statistic	P	5%
lnWTI	(C,0,1)	-2.7168	0.0751	-2.8939
d(lnWTI)	(C,0,0)	-7.4745	0.0000	-2.8936
lnER	(C,0,1)	-0.9269	0.7755	-2.8936
d(lnER)	(C,0,1)	-6.5327	0.0000	-2.8940

Nonlinear structure test. Here, we employ the BDS test, McLeod-LI test as well as RESET test to investigate whether there exists the nonlinear structure of oil price and exchange rate under VAR model. The results in Table 2 indicate that both of the series reject the null hypothesis of independent identity distributions at 1% significant level, therefore, the nonlinear structure between the two series is reasonable, which is conform to study results of previous study of developed countries. To properly find the relations between the two variables we must apply the nonlinear approach instead of the traditional linear one.

Table. 2 Result of the Nonlinear Structure Test

lnWTI BDS	McLeod-LI	RESET	lnER BDS	McLeod-LI	RESET
1.5262***	25.1180***	2.7862**	1.5325***	28.4508***	5.9213**

Note: this table reports the nonlinear structure test results of BDS, McLeod-LI and Reset test.
** denotes rejections of null hypothesis at 5% significant level.
*** denotes rejections of null hypothesis at 1% significant level.

Nonlinear Granger causality test. In this part, we employed the Diks and Panchenko's (2006) nonparametric Granger Test, Table 3 reports the test results. Following Diks' previous work, we discuss the results for lag length l_x=l_y=n (n=1, 2, 3, 4, 5, 6), the main task is to test the nonlinear causality for VAR residuals. From the report, we can find there is only the unidirectional nonlinear causality running from crude oil price to RMB exchange rate at 10% significant level, and this relation merely appear with 1 month lag length which suggests that change of crude oil price could lead to exchange rate fluctuate after one month time. In addition, Table 3 also shows that there nonlinear Granger causality does not exist between exchange rate and oil price in Chinese market.

	WTI does not Granger cause ER		ER does not Granger cause WTI	
l_x=l_y	T_n Statistic	P-Value	T_n Statistic	P-Value
1	0.5745	0.2828	-0.7796	0.7822
2	1.3468*	0.0890	0.4108	0.3406
3	0.5530*	0.0901	1.2732	0.1015
4	1.4471*	0.0739	0.5749	0.2827
5	1.4547*	0.0728	0.1691	0.4329
6	0.8664	0.1931	0.0334	0.4867

Note: l_x=l_y denotes the lag length of the residual.
* denotes rejections of null hypothesis at 10% significant level.

Table. 3 Nonlinear Granger Causality Test

Conclusions

Different from the wide range of research conducted by traditional Granger causality test, the causality relationships between oil price and renminbi exchange rate is nonlinear which often be ignored by previous studies. In order to fill this gap, we employ the nonparametric causality test proposed by Diks and Panchenko's (2006) to find whether the relationship between the world crude oil price and Chinese exchange rate is nonlinear as well as the direction of the causality relation. Our findings suggest the nonlinear structure between oil price and RMB exchange rate, and the nonlinear causality is running from crude oil price to exchange rate, but not vise versa. This result indicate that gasoline price movement can cause the co-movement of renminbi with a one-month lag.

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