Food versus Crude Oil: What Do Prices Tell Us?

Evidence from China

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Abstract This study investigates the causal relationship between the prices of rice, crude oil, wheat, corn and soybean in China, using monthly price data over the period of January 1998 to December 2013. Employing an autoregressive distributed lag (ARDL) bounds test, we explore the cointegration relationship among the price variables. We estimate the ARDL long-run price relationship and the short-run error correction process (ARDL-EC). The results show that rice price are affected by crude oil, wheat, corn and soybean price as the forcing variables. Both the long-run and short-run price transmission elasticity estimates suggest the importance of crude oil price on the formation of rice prices in China. Furthermore, the adjustment speed coefficient is found to be statistically significant, supporting the notion that there is an error correction mechanism for maintaining the long-run price relationship facing short-run shocks.

Keywords: food prices, crude oil price, long-run and short-run relationships, ARDL-EC model

1. Introduction

Previous empirical results have found that crude oil price volatilities have exerted tremendous impacts on the formation of food prices in the world market (Udoh, 2012; Esmaeili and Shokoohi, 2011). Crude oil price plays a key role in determining the production cost and, hence, the prices of agricultural commodities. Further, as early as 1983, Barnard indicated that fuel ethanol would be potentially a disruptive factor to global agricultural commodity prices. Due to the expansion of the biofuel market, grain producers have experienced increasing demand for their production beyond the traditional needs of food and feedstuffs. Anecdotally, one observes significant concurrent increases in both crude oil and grain prices in the world market during the period of 2005- 2008.[1] Analyzing the relationship between crude oil price and agricultural commodity prices is critical for the understanding of agricultural price movements.

As to the Chinese markets, several facts should be pointed out. First, after ten years consecutive increase in food production during 2004-2013, China has generated substantial food reserves to response the food crisis. However, the prices of food commodities have been rising steadily during this period. Second, it is expected that food and crude oil prices will be more closely linked in China in future years (Huang et al, 2009; Zhang, Wu and Shen, 2008). Further, Chinese consumption of crude oil has reached 415 million tons in 2011, of which imports accounts for 55.1%. **Thus, increasing fluctuations in world crude oil prices in the future can be expected to have great impacts on domestic grain prices in China**. Third, since 2004 China has implemented a fertilizer and diesel fuel subsidies to rural households, entitled General Agricultural Means Production Subsides. The amount of these subsidies is subject to adjustment when there are changes in fertilizer and diesel prices, which are linked to world crude oil price. **Thus, the fertilizer and fuel subsidies have the potential effect of reducing the link between crude oil price and grain prices in China.** Given the above different forces at play, empirical work analyzing the relationship between curde oil price and grain prices in China is of great importance for policy purposes.

The purpose of the paper is three-fold: (1) to investigate whether a long-run relationship exists between crude oil, rice, wheat, corn, and soybean prices using an Auto-Regression Distributed-Lag (ARDL) bound test, (2) to estimate that long-run price relationship (if exists) to measure the degree of price transmission, and (3) to estimate the corresponding short-run error-correction model to gain insight into the short-run adjustment toward the long-run price relationship. Information on the extend of market integration, including the degree of price transmission and the speed of short-run adjustment, is a crucial first step to understand agricultural price movements in China.

This paper is organized as follows: Section 2 provides a brief literature review; Section 3 describes the data source and the empirical models; Section 4 reports the empirical results; and Section 5 contains a summary and conclusions.

2. Brief Literature Review

Gohin and Chantret (2010) investigated the long-run relationship between the prices of several food commodities and energy products in world market using Computable General Equilibrium model, and found that real income effect had contributed to a negative relationship between food and energy prices, but the cost push effect had led to a positive relationship. Chen et al. (2010) incorporated both production and demand of food and energy crops in a global cropland allocation model. The authors found a significant direct relationship between crude oil price and food prices because of the demand for corn and soybeans from bio-fuel sector. Abdel and Arshad (2008) suggested increasing petroleum price was one of the factors that contributed to the rise in agricultural commodity prices, and found a strong evidence of long-run equilibrium relation between the petroleum and vegetable oil prices in world market. More recently, Nazlioglu and Soytas (2012) employed panel cointegration and Granger causality methods for a panel of twenty four agricultural products to examine the dynamic relationship between world oil prices and agricultural commodity prices. Their results provided further evidence on the causal relationship between world oil price and agricultural commodity prices. However, contrary statements were also made by previous studies. For example, Reboredo (2012) found a non-contagion relationship between world crude oil and global agricultural prices, using copulas models for weekly data from Jan. 1998 to Apr. 2011.

For Chinese markets, Huang et al. (2009) and Zhang and Zhang (2009) demonstrated that the rising oil price and the development of biofuel had significant effects on agricultural prices. Huang et al. found crude oil price to be an important influencing variable for the grain prices, including corn, soybeans, wheat, and rice grain prices, including corn, soybeans, wheat, and rice. The implication is that the development of bio-ethanol would not only increase the demand for energy crops such as corn and soybeans, but also indirectly affect other agricultural commodity prices (Qiu, Yang and Huang, 2009). Zhang, Wu and Shen (2008) found that the development of bio-fuels had no obvious effect on food security in China in the short-run, but could affect food prices to a significant extent over the long haul. On the contrary, Zhang and Reed (2008) found that world crude oil price is not an important variable affecting the prices of corn, soybeans and pork in China. Liu and Liu (2011) found no significant relationship between ethanol and corn prices whether in long-run or short-run, using Granger causality and error correction model. Likewise, Yang and Leatham (2012) found crude oil price to be not an important variable affecting rice price, wheat price, and corn price.

Focusing on the dynamic relationship of the prices, this paper investigates the causal relationship between crude oil price and major food commodities prices in China. The time price series include crude oil, rice, wheat, corn and soybean prices over the period of January 1998 to December 2013.

3. Data description and empirical model

3.1 *Data*

This paper investigates the relationship between agricultural commodity and crude oil prices in China. Four commodities are selected in the study: rice, wheat, corn and soybean. Since corn and soybeans can be produced for bio-fuel purposes and for food and feed grain purposes, one expects a close relationship between crude oil price and corn and soybean prices. One also expects a linkage between crude oil price and rice and wheat prices, because rice, wheat, corn and soybeans are substitutes in both production and consumption in China (competing for limited farm resources and limited consumer incomes).

The monthly price data for rice, wheat, corn and soybeans are obtained from Chinese Grain Website (Zhonghua Liang Wang).[2] The average price of early and late indica rice, and the Northeastern rice is used as the rice prices.[3] The prices for wheat, corn and soybeans are, respectively, grade #3 wholesale wheat price, grade #2 wholesale corn price, and grade #3 wholesale soybean price. As to the domestic crude oil price in China, we use the Daqing crude oil price, reported on the International Oil Website (Shijie Shiyou Wang).[4]

3.2 *The empirical model setting*

The ARDL modeling approach was originally introduced by Hendry (1995) and extended by Pesaran and Shin (1999), and Pesaran, Shin and Smith (2001). Using ARDL model to capture cointegrating non-stationary time series has advantages over the conventional methods of Engle and Granger (1987) and Johansen and Juselius (1990). First, the ARDL's bounds tests can be applied to series irrespective of whether they are integrated of order zero [i.e., I(0)] or order 1 [i.e., I(1)] or mutually cointegrated, whereas the conventional methods require all series be I(1). Second, the ARDL models generally provide unbiased estimates of long-run coefficients and valid t-statistics even when some of the regressors are endogenous (Phillips and Loretan, 1991). The conventional procedure of ordinary least squares, while super consistent, results in a biased estimate of the long run parameters, which is of intrinsic interest to this study. Third, the ARDL procedure can determine the cointegration relation in small samples, whereas Johansen's cointegration procedure requires larger sample sizes (Narayan, 2005).

To test for the existence of a long-run relationship among rice price (RP), crude oil price (OP), wheat price (WP), corn price (CP) and soybean price (SP), we specify the following equation:

$$\begin{aligned}\Delta \ln RP_t &= \alpha_0 + \alpha_1 \ln RP_{t-1} + \alpha_2 \ln OP_{t-1} + \alpha_3 \ln WP_{t-1} + \alpha_4 \ln CP_{t-1} + \alpha_5 \ln SP_{t-1} \\ &+ \sum_{i=1}^{n} \alpha_{1i} \Delta \ln RP_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta \ln OP_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta \ln WP_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta \ln CP_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta \ln SP_{t-i} + \mu_t \end{aligned} \quad (1)$$

where ln and Δ are the logarithmic and first-difference operators, respectively, and μ_t is the error term.[5] The existence of a long-run relationship among the five price series can be ascertained by the bounds test of Pesaran, Shin and Smith where the null hypothesis of no long-run relationship is $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$. Note that Equation (1) entails a specific normalization scheme of placing rice price as the left-hand-side variable. To assess the robustness of the test results, the other four normalization schemes of treating OP, WP, CP and SP as the left-hand-side variable will also be entertained.

Pesaran, Shin and Smith show that the asymptotic distributions of the associated F-statistic for the bounds test is non-standard under the null hypothesis that there exists no relationship in levels among the included variables. The authors provide two sets of asymptotic critical values for the F-statistic under the case in which all the variables are purely I(0) and the case where they are all purely I(1). If the computed F-statistic falls above the upper critical value bound, one can conclusively reject the null hypothesis of no relationship, regardless of whether the price series are I(0), I(1) or a mix of the two. On the other hand, if the computed F-statistic falls below the lower critical value bound, one would conclude that the null hypothesis of no relationship cannot be rejected. In the third case in which the F-statistic falls within the bounds, conclusive inference cannot be drawn and one would have to resort to unit-root pre-test and the associated conventional cointegration testing procedures.

If there is an evidence of long-run relationship (cointegration) among the price series, one would use the following ARDL model to estimate that long-run relationship:

$$\ln RP_t = \beta_0 + \sum_{i=1}^{Q_{RP}} \beta_{1i} \ln RP_{t-i} + \sum_{i=0}^{Q_{OP}} \beta_{2i} \ln OP_{t-i} + \sum_{i=0}^{Q_{WP}} \beta_{3i} \ln WP_{t-i} + \sum_{i=0}^{Q_{CP}} \beta_{4i} \ln CP_{t-i} + \sum_{i=0}^{Q_{SP}} \beta_{5i} \ln SP_{t-i} + \zeta_t \quad (2)$$

where ζ_t is the error term and Q_x is the number of lagged terms for variable x. The optimal lag lengths for the variables will be determined by Akaike Information Criterion (AIC). Lütkepohl (2006) pointed out that AIC has superior predicting properties to other lag-length selection criteria when data sample size is small (such as ours).

In equation (2), the contemporaneous rice price is explained by its lagged values as well as the contemporaneous and lagged values of other prices, including crude oil price. To illustrate the computation of the long run transmission elasticity of rice price with respect to a change in crude oil price, collapse other price terms on the right-hand side of (2) onto the constant term (C) and rewrite the equation as:

$$A(L,Q_{RP})\ln RP_t = C + B(L,Q_{OP})\ln OP_t + \zeta_t \tag{3}$$

where $A(L,Q_{RP}) = 1-\beta_{11}L-\ldots\beta_{1Q_{RP}}L^{Q_{RP}}$, and $B(L,Q_{OP}) = \beta_{20}+\beta_{21}L+\ldots+\beta_{2Q_{OP}}L^{Q_{OP}}$.

The long-run price transmission elasticity of RP with respect to OP can then be computed as (Wilson and Chaudhri, 2004):

$$\frac{B(1,Q_{OP})}{A(1,Q_{RP})} = \frac{\beta_{20}+\beta_{21}+\ldots+\beta_{2Q_{OP}}}{1-\beta_{11}-\ldots\beta_{1Q_{RP}}},$$

where the asymptotic standard errors of the long-run price transmission elasticity coefficient can be computed by the regression approach proposed by Bewley (1979).

The long-run price relationship in (2) can be used to specify the corresponding short-run error-correction model: ARDL-EC. Error correction models was first proposed by Granger (1981) and extended by Engle and Granger (1987). Given the existence of a long-run equilibrium relationships (cointegration), it is always possible to use an error correction model to capture the nature of short-run adjustment toward the long-run equilibrium relationship. The ARDL-EC model is specified as:

$$\Delta\ln RP_t = \theta_0 + \sum_{i=1}^{Q_{RP}}\theta_{1i}\Delta\ln RP_{t-i} + \sum_{i=0}^{Q_{OP}}\theta_{2i}\Delta\ln OP_{t-i} + \sum_{i=0}^{Q_{WP}}\theta_{3i}\Delta\ln WP_{t-i} + \sum_{i=0}^{Q_{CP}}\theta_{4i}\Delta\ln CP_{t-i} + \sum_{i=0}^{Q_{SP}}\theta_{5i}\Delta\ln SP_{t-i} + \theta_6 EC_{t-1} + \varepsilon_t \tag{4}$$

where EC is the error correction term and is taken from the estimated residuals in the long-run relationship in equation (2). The coefficients θ_{20}, θ_{30}, θ_{40}, and θ_{50} are the short-run rice price transmission elasticities with respect to crude oil price, wheat price, corn price, and soybean price, respectively. The coefficient θ_6 associated with the lagged error correction term provide information on how fast the market adjusts to maintain the long-run relationship in (2), following a shock to the system. As such, one expects θ_6 to be a negative coefficient. The proportion of the shock adjusted after m periods can be computed as $1-(1+\theta_6)^m$. As in the case of (2), the AIC criterion is used to select the lag lengths in equation (4).

4. The Empirical Analysis

4.1 *Stationary test of each series*

Unlike the conventional procedures (e.g., Engle and Granger, Johansen and Juselius), uniformity in the order of integration of the time series is not required in the ARDL model, although the order of integration cannot be greater than one. The Augmented Dickey-Fuller (ADF) (1979, 1981) and Phillips-Perron (PP) (1988) tests are used to test for unit roots. The results are in Table 1. While both ADF and PP tests reject the null hypothesis that the soybean price (SP) contains a unit root, both tests fail to reject the same null for the crude oil price (OP), rice price (RP), wheat price (WP) and corn price (CP). The same tests reject the null hypothesis that ΔOP, ΔRP, ΔWP, and ΔCP contains a unit root. The test results thus suggest a mixture of I(0) and I(1), with SP being I(0) and OP, RP, WP and CP being I(1). Given that the order of integration is not uniform for the price variables, the ARDL model is appropriate for the current study.

4.2 *ARDL Bound Cointegration Test*

For expositional purposes, equation (1) has rice price as the dependent variable and other prices as the forcing variables. The empirical analysis entertains several alternative specifications for the Bounds test, including different normalization schemes of specifying other price variable as the dependent variable as well as different sets of right-hand-side forcing variables. Comparing F-statistic against the critical value bounds, one assesses the appropriateness of alternative specifications of the long-run price relationship. For notational purposes, use F(X|Y|Z) to denote a version of equation (1) that includes X as the dependent variable, Y as the forcing variable, and Z as the excluded variable. The models entertained are listed in the first column of Table 2. For example, F(RP|OP, CP, SP|WP) represents a variation of equation (1) that takes the following form:

$$\Delta \ln RP_t = \alpha_0 + \alpha_1 \ln RP_{t-1} + \alpha_2 \ln OP_{t-1} + \alpha_4 \ln CP_{t-1} + \alpha_5 \ln SP_{t-1} + \sum_{i=1}^{n} \alpha_{1i} \Delta \ln RP_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta \ln OP_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta \ln CP_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta \ln SP_{t-i} + \mu_t$$

Pesaran and Smith (2001) reports bounds test critical values for sample sizes larger than 500 observations. Given the relatively small sample size of the current study (192 observations, with the effective sample size being 187 due to the lag terms in ARDL), we use the small-sample-size critical values (30~80 observations) reported in Narayan (2005).

The F-statistics for alternative specifications of long-run price relationship are reported in column 2 of Table 2, where single and triple asterisk denote 10% and 1% significance, respectively. The null hypothesis of no cointegration is rejected only for the three models in which rice price is specified as the dependent variable. The rejection of the specifications of treating crude oil price, corn price and soybean price as the dependent variable is intuitive, given the importance of imports in those three commodities in China. Because of Chinese government's self-sufficiency policy in major grains, on the other hand, rice and wheat prices are determined domestically.[6] While rice and wheat prices are regulated by Chinese government, the extent of regulation is much more severe in the case of wheat, which may explain the rejection of the specification of treating wheat price as the dependent variable.[7]

Based on the test statistics, the selected model is F(RP|OP, WP, CP, SP), which is equation (1). Rice price is a function of wheat price, corn price and soybean price because they are substitutes in both production and consumption. For example, as income increases in China, the demand for meat products increases and hence the demand for corn and soybeans increases, pushing up the prices of corn, soybeans, and rice. Rice price is a function of crude oil price because the latter affects the costs of rice production and transportation.

4.3 *The results on long-run relationships*

Based on the result of cointegration bound test, we estimate the long-run relationship between rice price and lagged prices of rice as well as contemporaneous and lagged prices of crude oil, wheat, corn, and soybeans (see Eq. (2)). As discussed, the lengths are determined based on the AIC statistics. The estimated long-run rice price transmission elasticities are reported in Table 3.

The long-run price transmission coefficients are all significant at 1% level, with the exception of soybean price. Crude oil price has a statistically significant effect on rice price: a 1% increase in crude oil price increases rice price by 0.087%. Similarly, wheat and corn prices have important impact on rice price: a 1% increase in the wheat and corn prices increases rice price by 0.708% and 0.417%, respectively. The strong price linkages between rice price and wheat and corn prices are as expected; the three commodities are substitutes in human and animal consumptions, as well as in production. The significant price transmission elasticity coefficient with respect to crude oil price supports the notion that an increase in crude oil price can cause an increase in the prices of corn and soybeans (because more of the commodities are diverted to bio-fuel purposes) and hence the price of other agricultural commodities (because of substitutions in consumption and production). This second round effect of crude oil price change, smaller in magnitude notwithstanding, turns out to be statistically significant.

To test for stability of the long-run price relationship over time, we utilize the cumulative sum of recursive residuals (CUSUM) test and the cumulative sum of squares of recursive residuals (CUSUMSQ) test proposed by Brown, Durbin and Evans (1975). This stability test is appropriate in time series data, especially when we do not know when a structural change might happen. The null hypothesis is that the coefficient vector is the same in every period and the alternative hypothesis is that they are different. The CUSUM and CUSUMSQ statistics are plotted against their 5% critical bound in Figure 1 and Figure 2. If the plot of these statistics remains within the critical bound, one fails to reject the null hypothesis of no structural change. The computed CUSUM and CUSUMSQ statistics are all within the 5% critical bounds, though the CUSUMSQ statistics fall slightly outside of the upper bound between February 2004 and October 2006. Overall, the results suggest a stable price relationship over the study period.

4.4 *The results on short-run relationships*

Given the estimated long-run price relationship, the short-run ARDL-EC model in (4) is estimated and the results are presented in Table 4. The short-run rice price transmission elasticity coefficient with respect to crude oil price is 0.022, with respect to wheat price is 0.177, and with respect to corn price is 0.292. The elasticity coefficient with respect to soybean price is again statistically insignificant at the 10% level. The coefficient of the lagged residual term in the ARDL-EC model is negative (-0.060) and significant at the 1% level, indicating that while there is an error correction mechanism for the maintenance of the long-run price relationship, the adjustment speed is minimal. Specifically, only 6% of the previous month's deviation from the equilibrium relation is corrected in the current month, and it takes almost 48 months to adjust for 95% of the deviation from the long-run relationship.

5. Concluding Remarks

This study investigated the relationship between rice, crude oil, wheat, corn, and soybean prices. A bounds test is used to test for the existence of cointegration relationship among the price variables. An autoregressive distributed lag (ARDL) model and an ARDL error correction model are estimated to estimate the long-run and short-run price transmission elasticities, respectively.

The bounds test results supports the existence of a cointegration relationship among the five price series. The results also support the normalization scheme of specifying rice price as a function of its own lags, as well as the contemporaneous and lagged values of crude oil, wheat, corn, and soybean prices. By so normalizing, the long-run rice price transmission equation was estimated and the corresponding long-run rice price transmission elasticities computed. We found significant long-run price transmission elasticities of rice with respect to crude oil price, wheat price and corn price. However, the rice price transmission coefficient with respect to soybean price is not statistically significant. As far as the corresponding short-run error correction model is concerned, the adjustment speed coefficient is statistically significant, although it takes about 48 months to correct for 95 percent of the short-run deviations.

The empirical findings have important policy implications. First, it shows that crude oil price has a statistically significant impact on the formation of rice price, both in the short run and long run. However, the magnitude of rice price transmission elasticity coefficient is much smaller with respect to crude oil price shocks than with respect to corn and wheat price shocks. This may provide some relief to the worry that shocks in the crude oil price in the world market may cause excessive price fluctuations in the rice market in China. The study finds that shocks in other Chinese agricultural commodity price exert greater impacts on the fluctuations of rice price in the nation. Second, it is of interest to identify reasons underlying the relatively small adjustment speed coefficient (albeit statistically significant) found in this study, including possible structural and policy impediments to a speedy return to the long-run equilibrium price relationship upon shocks.

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Table 1 Unit Root Tests

Variables	ADF	PP
lnOP	-3.0951	-2.8361
lnRP	-2.7891	-2.4022
lnWP	-2.5730	-2.5302
lnCP	-3.0314	-2.7584
lnSP	-3.3289***	-3.5666**
ΔlnOP	-10.4353*	-10.4517*
ΔlnRP	-5.49827*	-10.9671*
ΔlnWP	-9.3992*	-9.4378*
ΔlnCP	-8.3941*	-7.3938*

Notes: ADF and PP unit root tests include an intercept and trend. Critical values for the ADF and PP unit root tests are as follows: 1% (a) -4.0071, 5% (b) -3.4337, and 10% (c) -3.1407. *, ** and *** indicate 1%, 5% and 10% significance respectively.

Table 2 Bound F-test for Cointegration

Cointegration Hypotheses	F-statistics	H_0: No Cointegretaion
F(RP|OP, WP, CP, SP)	5.9776***	Reject
F(RP|OP, WP, CP|SP)	5.4711***	Reject
F(RP|OP, CP, SP|WP)	4.0009*	Reject
F(OP|RP, WP, CP, SP)	3.3378	fail to reject
F(WP|OP, RP, CP, SP)	2.5505	fail to reject
F(WP|OP, CP, SP|RP)	3.2309	fail to reject
F(CP|OP, RP, WP, SP)	1.8043	fail to reject
F(CP|OP, RP, WP|SP)	1.7435	fail to reject
F(CP|RP, WP, SP|OP)	0.54057	fail to reject
F(CP|RP|OP, WP, SP)	0.90131	fail to reject
F(CP|WP|OP, CP, SP)	0.17915	fail to reject
F(CP|RP, WP|OP, SP)	0.41886	fail to reject
F(SP|OP, RP, WP, CP)	2.4995	fail to reject
F(SP|OP, RP, WP|CP)	1.8778	fail to reject
F(SP|RP, WP, CP|OP)	1.4697	fail to reject
F(SP|RP|OP, WP, CP)	1.6137	fail to reject
F(SP|WP|OP, RP, CP)	1.3950	fail to reject
F(SP|RP, WP|OP, CP)	1.6605	fail to reject

Narayan's Critical value bounds vary depend on the number of forcing variables, denoted below as *k*.

If *k*=1, critical values = 7.095-8.260, 5.060-5.930, 4.135-4.895 for 1%, 5% and 10% significance levels, respectively.

If *k*=2, critical values = 5.407-6.783, 3.940-5.043, 3.260-4.247 for 1%, 5% and 10% significance levels, respectively.

If *k*=3, critical values = 4.568-5.960, 3.363-4.515, 2.823-3.885 for 1%, 5% and 10% significance levels, respectively.

If *k*=4, critical values = 3.817-5.122, 2.850-4.049, 2.425-3.574 for 1%, 5% and 10% significance levels, respectively.

Table 3 Long-run Elasticities Estimates

Variable	Coefficient	Standard Error	T-Ratio[Prob.]
Constant	-0.23987	0.019133	-1.0042[0.317]
OP	0.087076	0.081996	4.5511[0.000]
WP	0.70761	0.072174	8.6298[0.000]
CP	0.41706	0.060920	5.7786[0.000]
SP	-0.079092	0.23886	-1.2983[0.196]

Table 4 Error Correction (ECM) Specification for the ARDL model

Variable	Coefficient	Standard Error	T-Ratio[Prob.]
Constant	-0.059971	0.058041	-1.0333[0.303]
ΔRP_{t-1}	0.22189	0.064936	3.4170[0.001]
ΔRP_{t-2}	0.10764	0.063438	1.6967[0.092]
ΔRP_{t-3}	0.14683	0.063770	2.3025[0.022]
ΔOP	0.021770	0.0062246	3.4974[0.001]
ΔWP	0.17691	0.035357	5.0035[0.000]
ΔCP	0.29225	0.076376	3.8265[0.000]
ΔCP_{t-1}	-0.20989	0.080745	-2.5994[0.010]
ΔSP	0.078985	0.049540	1.5944[0.113]
ΔSP_{t-1}	0.023716	0.044467	0.53333[0.594]
ΔSP_{t-2}	-0.084669	0.038738	-2.1857[0.030]
ΔSP_{t-3}	-0.12534	0.040061	-3.1286[0.002]
ECM_{t-1}	-0.059971	0.036836	-6.7871[0.000]

Notes: The lag lengths are selected using Akaike's information criterion.

Figure 1: Plot of Cumulative Sum for ECM

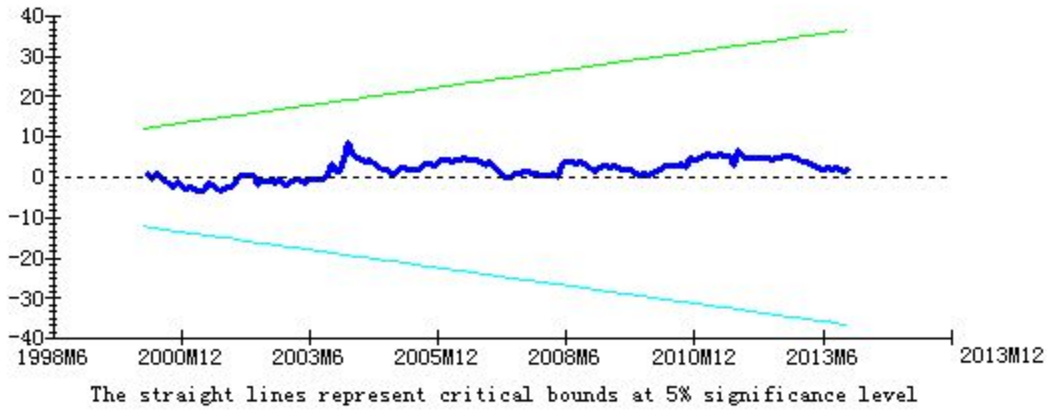
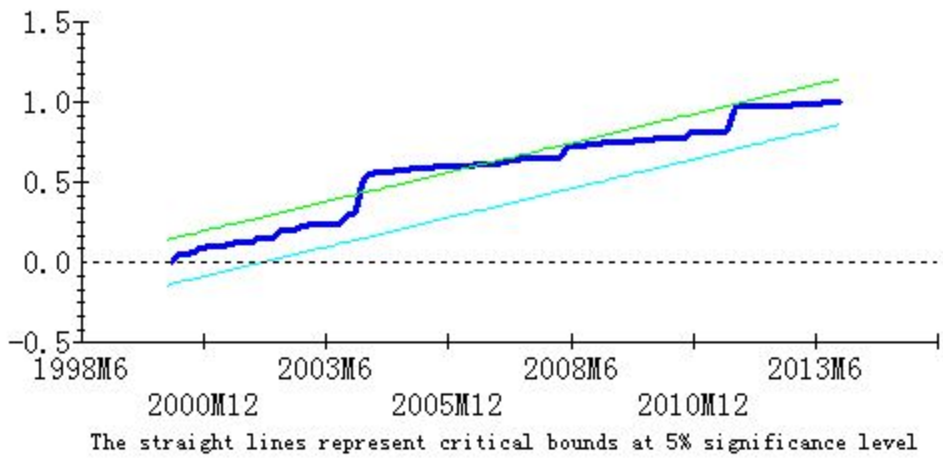


Figure 2: Plot of Cumulative Sum of Square for ECM



Note

[1] For example, the crude oil price of West Texas Intermediate reached $133.93 per barrel in June 2008, representing a rise of 180% from $47.83 per barrel in January 2005. During the same period, rice price in the world market rose by 352%.

[2] The website link is http://www.cngrain.com.

[3] According to the real consume customer in China, we use the formula ((early indica rice price + late indica rice price)/2 + The Northeast rice price)/2 to calculate the rice price.

[4] The website link is http://oil.in-en.com/quote/spot-oil.asp. The website reports daily Daqing crude oil prices, which were converted to monthly data for the purpose of this study.

[5] Pesaran and Shin (1999) recommended choosing a maximum of 2 lags for annual data, and more than two lags can create problems related to degree of freedom. For our monthly data, the computer program, *Microfit*, specifies 4 as the maximum lag length, n.

[6] The "**Medium- and Long-term Plan for National Food Security**", released on November 13, 2011 by the National Development and Reform Committee, seeks to achieve a self-sufficiency level of 95% in major grains. This is, in part, to be accomplished by maintaining a reasonable level of grain storage, of which no less than 70% should be in wheat and rice.

[7] For example, from early December 2009 to early January 2010, rice prices rose by 228 yuan a ton from 2120 yuan per ton to 2348 yuan per ton. During the same period, wheat prices rose only 27 yuan per ton, in part due to government's auction off 1.58 million tons of wheat.