The Long Run Relationship Between Petroleum And Cereals Prices: Evidence From Cointegration Tests

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This study seeks to investigate whether or not there is a long-term relationship between Petroleum and cereals prices. To that end, the bivariate cointegration approach using Engle-Granger two-stage estimation procedure is applied. The study utilises monthly data over the period of January 1980 until March 2008. The results show that there is evidence of long-run equilibrium relation between the two products prices. The estimates of the error correction models reveal a unidirectional long- run causality flowing from petroleum to cereals prices.

Field of Research: Agricultural Economics, Price Analysis

1. Introduction

The last few decades saw an increase in primary commodity prices after a downward trend in the 1970s until the beginning of the 21st century (World Bank, 2007). As shown in Figure 1, the price index for all primary commodities has increased 204% between January 2000 and March 2008 (International Monetary Fund, 2008). The major source of increase is petroleum which registered an increase of more than 300% while food has increased by 107%. Among the food items, the cereals have experienced a considerable increase of 192%. In fact between January 2006 until March 2008, the cereals prices have undergone the largest increase (132%) compared to all commodities (60%) and food commodities (68%).

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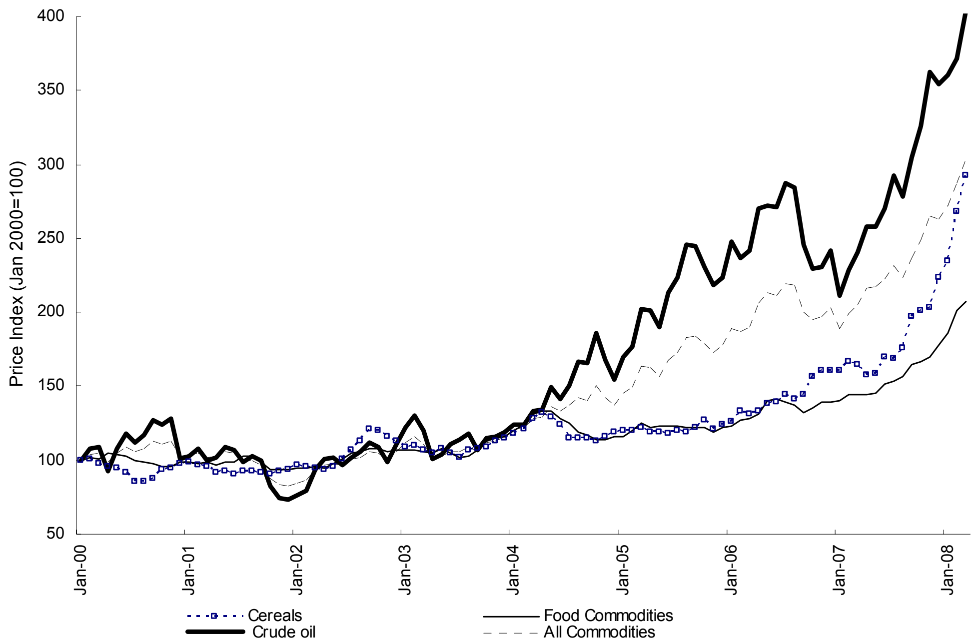

Figure 1: Price Indices of Commodities, January 2000-February 2008
Source: International Monetary Fund: IFS online database (2008).

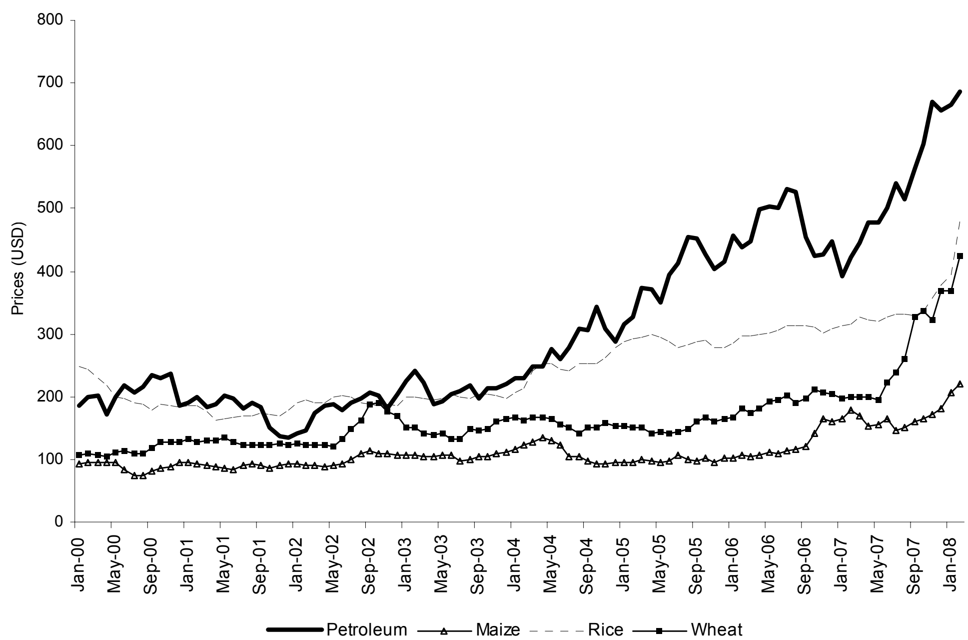

Figure 2: Prices of Petroleum[a], Maize, Rice and Wheat, January 2000-February 2008 (USD per tonne)
Source: International Monetary Fund: IFS online database (2008).
a: USD per barrel

Narrowing into the cereals, it is clear that the prices of these commodities have shot up at a relatively higher rate beginning of the late 2006 (Figure 2). For instance, the price of wheat has increased from USD196 per tonne to USD425 per tonne in February 2008 while the price of rice increased from USD313 per tonne to USD481 (IFS, 2008). In terms of price indices, maize and wheat have increased 137% and 302% respectively between January 2000 to March 2008 (Figure 3).

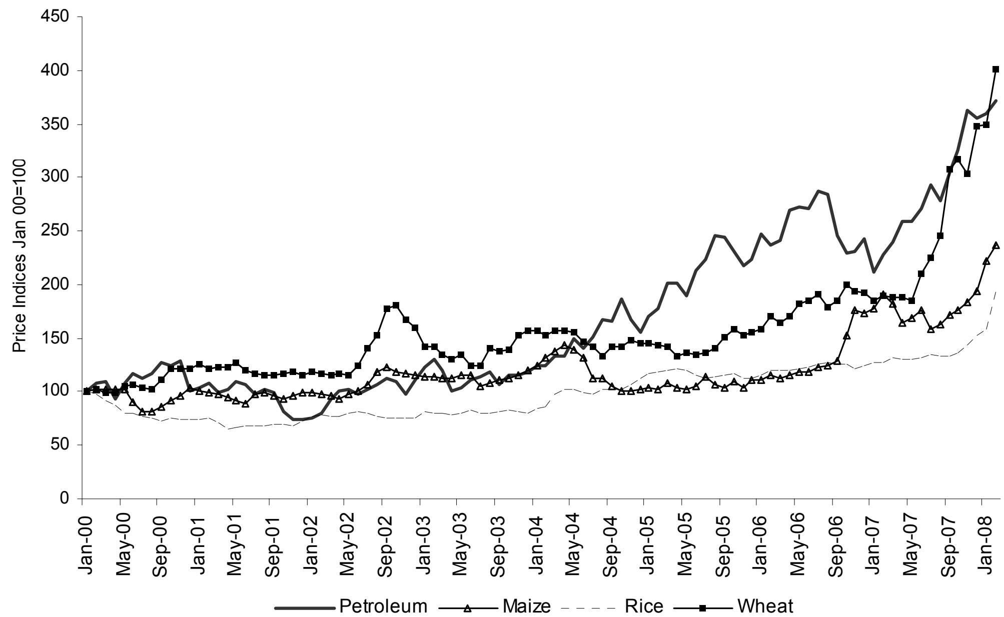

Figure 3: Prices Indices of Petroleum, Maize, Rice and Wheat, January 2000=100
Source: International Monetary Fund: IFS online database (2008).

The increase in the price of cereals was largely attributed to inadequate supply as against to the growing demand of these commodities worldwide. On the supply sector, the production was constrained by a number of factors. In the case of rice, the production was affected by poor weather in the major producing areas such as Vietnam and China. But largely, it is due to slow improvement in paddy productivity as a result of reduction in the public investment in R & D among the developing economies. Rising energy prices is cited to be one of the prime reasons behind the surge in the cereal prices (USDA, IFAD, FAO, 2008). Crude oil price index has increased 272% between January 2000 and March 2008 (Figures 1 – 3). High energy prices led to the increase in agricultural cost of production and also triggered the demand for alternative energy sources such as biofuels. The U.S. government has been subsidizing farmers to grow crops for energy resulting in a massive shift in corn cultivation. Approximately 30 percent of U.S. corn output is channelled towards ethanol production in 2008 instead going into world food and feed markets. Ethanol production has also resulted in the conversion of planting area of cereal crops such as wheat and rice to corn and this further reduces the world food supply.

Population and income growth in the fast moving economies in China and India have been the forces driving food demand particularly rice and meat products. Increase in demand for meat and dairy products further induced the demand for feedstuffs which are corn and soybean based. Increase in cereal prices is a major concern to most of the developing countries as rice is the staple food of the population. Hence, an increase in the price of rice will affect the poor consumers much more than the well to do ones. The apparent high correlation between petroleum and cereal prices begs the question as to the nature of the relationship of the two variables. Hence, this paper intends to examine the co-movements of the petroleum and cereal prices and explain the cointegration and causality between them.

2. Methodology

The study adopts a simple model to express the relationship between petroleum and each of the major cereals prices and test the hypothesis of whether or not changes in petroleum prices play an important role in changing them.

$$C_i P_t = \alpha'_0 + \alpha'_1 PP_t + v'_t \qquad (1)$$

where C_iP_t is cereal (i) price at time t, PP_t is crude oil price, and v'_t is the error term.

To investigate whether or not a stable linear steady-state relationship exists between the variables under study, we need to conduct unit-root and cointegration tests for them. Unit-root tests show if a time-series variable is stationary. This study applies both The Augmented Dicky-Fuller (ADF) (Dickey and Fuller, 1981) and Phillips Perron (PP) (1989) unit-root tests to decide the order of integration of the series of the two variables. According to Engle and Granger (1987), two I(1) series are said to be cointegrated if there exists some linear combination of the two which produces a stationary trend (I(0)). In other words, cointegrated series are related over time. Any non-stationary series that are co integrated may diverge in the short run, but they must be linked together in the long run. Therefore, co integration suggests that there must be Granger causalities in at least one direction, at least one of the variables may be used to forecast the other. Moreover, it has been proven by Engle and Granger (1987) that if a set of series are co integrated, there always exists a generating mechanism, called “error-correction model”, that restricts the long run behaviour of the endogenous variables to converge to their counterbracing relationships, while allowing a wide range of short-run dynamics.

Thus, the second step of this investigation is to check for the existence (or absence) of cointegration. Here, the Johansen (1991) test, which has the advantage that both estimation and hypothesis testing are performed in a unified framework, is utilized. The Johansen approach has been extensively documented so we will only briefly describe the setup and testing procedure

(Johansen, 1988 and Johansen and Juselius, 1990). Johansen (1988) uses the vector error correction model (VECM) as a starting step for estimation. From a vector autoregression (VAR) of order *p* the $k \times 1$ vector of *I*(1) variables Y_t can be defined as:

$$Y_t = \mu + \sum_{i=1}^{p} A_j Y_{t-i} + \varepsilon_t \qquad (2)$$

where ε_t is an i.i.d. error term. The VAR model (3) can be parameterized in a Vector Error Correction Model (VECM) form can be found by solving the change in Y_t as follows:

$$\Delta Y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} - \Pi Y_{t-1} + \varepsilon_t \qquad (3)$$

Where $\Gamma_j = -\sum_{j=i+11}^{p} A_i - I$, $\Pi = \sum_{i=1}^{p} A_i - I$

The long-run information is found in the Π matrix and the rank of this matrix determines the number of cointegrating relationships. If the rank of Π equals *p* (the size of the *Yt* matrix) then Y*t* themselves are stationary. If the rank is less than *p* but greater than zero then some independent unit roots exist. If *p* equals zero, then all unit roots are independent. If the rank *r* is 0 < *r* < *p* then Π can be decomposed using a reduced rank regression into $\Pi = \alpha\beta'$. Because the rank of Π is usually unknown, Johansen proceeds to develop test procedures (The Trace and The maximum eigenvalue test statistics) to test the rank of Π. The tests are based on the eigenvalue solution to the reduced rank regression.

Trace statistic = $-T \sum_{i=q+1}^{N} \ln(1-\hat{\lambda}_i)$

where $\hat{\lambda}_i$ is the estimated eigenvalue and *q* is the null hypothesis that at most *q* cointegrating vectors exist. The alternative hypothesis is that at least one more cointegrating vector than the null exists (i.e. *r* > *q*). The maximum eigenvalue which tests the null hypothesis of q cointegrating relations against the alternative of q+1cointegrating relations can be computed as:

The maximum eigenvalue statistic, $= -T \ln(1-\hat{\lambda}_{q+1})$ for q =0,1,..,k-1.

The final step of our investigation is to examine the underlying causal relationship between the two variables within a bivariate framework. We employ the Granger (1969, 1980) causality test because of its favourable finite sample properties as reported in Guilkey and Salemi (1982) and

Geweke et al. (1983). In the bivariate case, the causal or error correction model can be written as follows:

$$\Delta y_t = \alpha_0 + \delta e_{t-1} + \sum_{m=1}^{M} \alpha_m \Delta y_{t-m} + \sum_{n-1}^{N} \beta_n x_{t-n} + \varepsilon_t \quad (4)$$

where y_t is the dependent variable(can be PP or CiP), x_t is the independent variable and e_{t-1} is an error-correction term (ECT). According to Granger (1988) and Miller and Russek (1990), there are two potential sources of causation of y_t by x_t in the error correction model similar to Equation 3, either through β_n or through the ECT (i.e., whether or not $\delta=0$). In contrast to the standard Granger causality test, model (4) allows for the detection of a Granger causal relation from x_t to y_t, even if the coefficients on lagged difference terms β_n in y_t are not jointly significant. Thus, ECT measures the long run causal relationship while β_n determine the short run causal relation. Granger (1988) further notes that cointegration between two or more variables is sufficient to indicate the presence of causality at least in one direction.

The sign and the magnitude of the coefficient of the error correction term (ECT) helps in figuring out the short-term adjustment process. If the value of the coefficient lies between 0 and -1, the ECT tends to cause the dependent variable to converge monotically to its long-run equilibrium track in relation to variations in the exogeneous "forcing variables", and the greater the magnitude of the coefficient of the error term the greater the response (speed of adjustment) of the dependent variable to the corresponding error correction term. A negative value of the coefficients of the ECT, or a value smaller than -2, will cause dependent variable to diverge. If the value is between -1 and -2, then the ECT will produce dampened fluctuations in the dependent variable about its equilibrium route (Alam and Quazi, 2003).

2.1 Data

The sample periods chosen for this study extend from January 1980 to the March 2008. Maize and wheat prices are represented by United States maize and wheat (Gulf Ports) prices, Thailand Rice (Bangkok) represents rice prices (in USD per tonne) whilst the world average crude petroleum prices represent petroleum prices (USD per barrel). All price variables are nominal and are expressed in the normal form. The data is provided by the International Financial Statistics (IFS) online service.

3. Discussion of Findings

3.1 Unit Root Tests

Table 3 shows the results of ADF and PP unit root tests for the underlying price series in levels and first differences. The null hypothesis of existence of unit root cannot be rejected for each of the variables in the level and thus it is concluded that the series are non stationary with the presence of unit root.

However, the null hypothesis is rejected at the 1% level of significance for all of them in their first differences. This indicates that stationarity is achieved for them after the first differencing i.e. series are I(1).

Table 3: Unit Root Tests for Petroleum and Major Cereals Prices

Commodity	Variable	ADF		PP	
		Level	1st difference	Level	1st difference
Petroleum	P	1.977049	-14.527281**	2.502921	-14.41793**
Maize	M	-2.344599	-13.24011**	-1.599872	-12.93107**
Rice	R	-1.454586	-11.56799**	-1.364943	-11.46831**
Wheat	W	2.229900	-14.26325	2.261305	-14.79677

** denote 1 % significance level

Table 4: Johansen Cointegration Tests

Commodity	Test statistics	H_0: No Cointegrating Relation	H_0: At Most One Cointegrating Relation
Maize/Petroleum	Trace Statistics	15.58439* (0.0292)	0.035123 (0.8513)
	Max-Eigen Statistics	15.54927* (0.0312)	0.035123 (0.8513)
Rice/Petroleum	Trace Statistics	20.75881* (0.0073)	1.468301 (0.2256)
	Max-Eigen Statistics	19.29050 * (0.0074)	1.468301 (0.2256)
Wheat/Petroleum	Trace Statistics	33.62453* (0.0044)	8.670427 (0.2017)
	Max-Eigen Statistics	24.95410* (0.0070)	8.670427 (0.2017)

Numbers in parentheses give the asymptotic signifcance level (*p* values) estimated in MacKinnon *et al.* (1999).
* denotes rejection of the hypothesis at the 5% level

3.2 Cointegration Tests

Using Johansen's maximum likelihood approach we test the bivariate relationship between oil and each of the major cereals, as in Equation (1) .The trace and Max-eigenvalue statistic for testing the rank of cointegration are shown in Table 4. The results of both tests deny the absence of cointegrating relation between petroleum and cereals prices series. Furthermore, both tests suggest the presence of one cointegrating equation at 5% level.

Cointegration among the nonstationary prices of petroleum and the three cereals means that a linear combination of them is stationary and, consequently, prices tend to move towards this equilibrium relationship in the long-run.

3.3 Causality Tests

Granger causality tests highlight the presence of at least unidirectional causality linkages as an indication of some degree of integration. This implies that each market uses information from the other when forming its own price expectations, while unidirectional causality inform about leader-follower relationships in terms of price adjustments. The results of Granger causality test are presented in Table 5. On the basis of those results, this paper detects long run unidirectional causality from oil price to cereals prices. However, it denies the presence of a similar relation in the opposite direction. In addition, this paper finds that the coefficients of the ECT in the models with ΔC_iPs as dependant variables carry negative signs. This suggests that the ECT acts as a force which causes the integrated variables to return to their long run relation when they deviate from it in all the cases. Furthermore, the magnitudes of the error correction term indicate that it tends to correct the deviation at a low speed. With regard to the causality results, the following points merit emphasis.

First, the inclusion of an error correction term in these causal models ensures a proper test of the existence or absence of a material relationship between petroleum and cereals prices. Second, the error correction term not only measures disequilibrium, but also captures deviations from it. According to the results presented in Table 5, the coefficients of the error-correction term which measures the speed of adjustment of maize, rice and wheat prices to their equilibrium levels equals to 0.03, 0.05 and 0.02 respectively indicating that only 3 percent, 5 percent and 2 percent of the disequilibrium is corrected each month for each of them, which is relatively low speed. However the prices of maize adjust at a higher speed compared to the others while rice prices adjust at lowest speed. As for the short run causality, the results deny the existence of such relationship between oil prices and cereals prices in the short run.

Table 5: F-statistics for Tests of Granger Causality

Dependent Variables	Independent Variable(ΔPP) (F-statistic)	Coefficients of ECT	Causal Reference
ΔMP	1.962482 [0.1421]	-0.048587* (-3.84971)	PP $\xrightarrow{LR}$ MP PP $\not\xrightarrow{SR}$ MP
ΔRP	2.779343 [0.0964]	-0.023036 (-3.92207)	PP $\xrightarrow{LR}$ RP PP $\not\xrightarrow{SR}$ RP
ΔWP	0.729027 [0.4832]	-0.029602* (-3.42104])	PP $\xrightarrow{LR}$ WP PP $\not\xrightarrow{SR}$ WP

Note: Numbers in parentheses are t statistics, numbers in square brackets are *p* values and * denotes significance at 5% level.

The symbol "$\xrightarrow{LR}$"represent unidirectional causality in the long run.

The symbols " $\not\xrightarrow{LR}$" and " $\not\xrightarrow{SR}$ "denote absence of causality in the long run and the short run, respectively.

4. Conclusion

The results of Granger causality tests show that there exist a long run unidirectional causality from petroleum price to the three cereals prices, i.e., maize, rice and wheat. The said is not true for the reverse. These results suggest that petroleum price factor is growing in significance in the cereal complex. In the past, crude oil enters the aggregate production function of the commodities through the use of various energy-intensive inputs (such as fertilizer and fuel for agricultural commodities) and also transportation. However, lately, the high price of crude oil has increased the demand for biofuel such as ethanol which utilised maize as the feedstock. This in turn has increased maize production at the expense of wheat and the consequent price hikes of these two commodities as well as rice. The Clearly, further analysis on the workings of the cereal markets will have to incorporate crude oil prices as one of the major market determinants.

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