Examining the Evolving Correspondence Between Petroleum Prices and Agricultural Commodity Prices

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Abstract

Over the last few years, the production of renewable fuels has increased dramatically. Rising oil prices, limited supplies of fossil fuel, and increased concerns about global warming have created a growing demand for renewable energy sources. Both the ethanol and biodiesel industries have experienced tremendous growth in the past few years. The production of these fuels is highly dependent on the availability of agricultural feedstocks. This research examined the covariability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices during the 2003-2007 time period. Johansen cointegration tests revealed no cointegrating relationships during the 2003-2005 time frame. However, corn prices and soybean prices were cointegrated with crude oil prices during the 2006-2007 time period.

Keywords: energy, ethanol, biodiesel, renewable fuels, crude oil prices, cointegration

JEL Codes: Q11, Q13, Q42

INTRODUCTION

Over the last few years, the production of renewable fuels has increased dramatically. Rising oil prices, limited supplies of fossil fuel, and increased concerns about global warming have created a growing demand for renewable energy sources. Renewable fuels can provide a multitude of benefits to society. The renewable fuels industry has the potential to offset some imports on foreign oil as well as lower toxic emissions.

Both the ethanol and biodiesel industries have experienced tremendous growth in the past few years. The production of these fuels is highly dependent on the availability of agricultural feedstocks. U.S. Ethanol production is primarily fueled by corn, while the biodiesel market is primarily driven by soybeans. In Brazil, the ethanol industry relies mainly on sugarcane. As the production of renewable energy continues to rise, producers of these feedstocks are experiencing an increased demand for their commodities, which leads to higher prices. Corn prices, for example, have reached record levels in the past year, at least in part due to increased ethanol production. As oil prices rise and the demand for renewable fuels increases, the price of renewable fuel feedstocks may follow.

Yu et al. (2006) recently examined the relationship between crude oil prices and vegetable oils used in biodiesel production, including soybean, sunflower, rapeseed, and palm oil. Additionally, their study examined the interdependence among only the vegetable oils using cointegration analysis. Yu et. al (2006) found only one cointegrating vector among the vegetable oil and crude oil prices included in the study, which is an indicator of the degree of substitutability among the vegetable oils. The study found that crude oil price shocks did not have a significant impact on changing vegetable oil prices. Additional studies have also examined the relationships among various vegetable oils (Duncker, 1977; In and Inder, 1997;

Griffith and Meilke, 1979; Labys, 1977; Owen et al., 1997). In and Inder (1997) and Owen et. al (1997) both examined the correspondence between similar vegetable oil prices over a similar time frame. However, In and Inder (1997) found a long-run correspondence among vegetable oil prices, while Owen et al. (1997) did not observe a strong enough relationship among vegetable oil prices to consider them to be cointegrated.

Malliaris and Urrutia (1996) examined interrelationships among related agricultural futures contracts, including corn, wheat, oats, soybeans, soybean meal, and soybean oil and found that the futures contracts were correlated. In a similar study, Dawson and White (2002) used cointegration analysis to examine the relationships between barley, cocoa, coffee, sugar, and wheat futures. Results of their study identified only one cointegrating relationship between barley and wheat.

In this study, we examine covariability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices during the 2003-2007 time period. The main goal was to determine whether or not there is an increasing tendency for price changes in petroleum prices to correspond to price changes in selected agricultural commodities. The degree of covariability between crude oil prices and the prices of corn, sorghum, soybeans, and soybean oil was expected to be higher in 2006-2007 than in 2003-2005. Even though both ethanol and biodiesel were produced prior to 2006, it was hypothesized that agricultural feedstock prices did not become significantly associated with crude oil prices until the 2006-2007 time period. During the 2005-2006 time period, crude oil prices increased significantly allowing biofuels to be economic alternatives to fossil fuels. Therefore, the degree of correspondence was expected to be much higher for the 2006-2007 time period than for the 2003-2005 time period.

DATA

Weekly price data from 2003-2007 for corn, soybeans, soybean oil, palm oil, world sugar, and crude oil were used for this study (see figures 1-5). The data were obtained from Primark Datastream. The data were divided into two time periods, 2003-2005 and 2006-2007, and analyses were conducted on each data set.

BACKGROUND AND METHODOLOGY

A vector error correction model was employed to examine relationships between crude oil prices and feedstock prices. This methodology accounts for the possibility of nonstationarity in prices and cointegration relationships among price series. Vector error correction models consider both the long-run and short-run relationships among variables. Cointegration has become a widely used technique for analyzing issues associated with non-stationary time series data, while avoiding the problem of spurious regression. Spurious regression is an apparent significant long-run relationship between variables, when none is actually present. Cointegration between non-stationary variables occurs when the linear combination of the variables generates a stationary series (Engle and Granger, 1987).

Several methods are available to test for cointegration between variables. Two commonly used techniques are the Johansen approach and the Engle Granger approach. For this study, the Johansen and Jesulius cointegration method was utilized. The Johansen and Jesulius approach involves a multivariate autoregressive that provides a method of estimating multiple cointegration relationships (Johansen (1988), Johansen and Juselius (1990)). The following model in vector error-correction form was used for the present study.

(1) $\Delta \mathbf{z}_t = \boldsymbol{\Gamma}_1 \Delta \mathbf{z}_{t-1} + \ldots + \boldsymbol{\Gamma}_{k-1} \Delta \mathbf{z}_{t-k+1} + \boldsymbol{\Pi} \mathbf{z}_{t-k} + \mathbf{u}_t$

The estimates of $\boldsymbol{\Gamma}_i$ measure the short-run adjustment to changes in the endogenous variables, while $\boldsymbol{\Pi}$ contains information on the long-run cointegrating relationships between variables in the model. Testing for cointegration involves testing the rank of $\boldsymbol{\Pi}$**.** If $\boldsymbol{\Pi}$ has full rank, the variables are stationary. If the rank of $\boldsymbol{\Pi}$ is zero, no cointegration relationships are present. If $\boldsymbol{\Pi}$ has reduced rank, $\boldsymbol{\Pi}$ can be decomposed as $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta}'$, where $\boldsymbol{\alpha}$ represents the short-run speed of adjustment following a deviation from the long-run equilibrium relationship and $\boldsymbol{\beta}$ represents the long-run relationships between variables (Johansen and Juselius (1990)).

The Augmented Dickey-Fuller Test (ADF) developed by Dickey and Fuller (1979, 1981) and Said and Dickey (1984) is used to test the null hypothesis of a unit root for each variable. To determine if cointegration relationships exist between the variables, the lag length (k) and cointegration rank (r) must be determined. Johansen (1991) proposes a two-step method to first determine the lag length using either an information criterion or a likelihood ratio test and then to determine the cointegrating rank using a likelihood ratio test, such as the λ_{max} test[1] or the trace test.

RESULTS

The data series were tested for stationarity using ADF tests. The ADF tests indicated that all variables were nonstationary in levels (table 1) and stationary in first differences. Johansen cointegration tests were conducted on the data series for the time periods, 2003-2005 and 2006-2007. The cointegration tests revealed that none of the agricultural commodity price series were cointegrated with the crude oil price during the 2003-2005 time frame (table 3). However, corn

[1] λ_{max} test = $-T \log (1 - \lambda_{r+1})$, r = 0, 1, 2, …, *n*-2, *n*-1 where T is the sample size and λ_{r+1} is the eigenvalue corresponding to r + 1 cointegration vectors. Test the null hypothesis of r cointegration vectors vs. the alternative of r + 1 cointegration vectors.

and soybean prices were cointegrated with the crude oil price during the 2006-2007 time period (table 4). The Schwarz Information Criterion (SIC) indicated an optimal lag length of one. Tests for weak exogeneity indicated that the crude oil price was weakly exogenous in both cointegrating relationships. Therefore, crude oil prices do not adjust to changes in corn and soybean prices. Analysis of the data series seems to indicate that a significant change occurred at the end of 2006. Therefore, correlation coefficients were computed for each price series and crude oil prices for the 2003-2006 time period and the 2007 time period (table 5). Corn prices have a positive, but low correlation with crude oil prices in 2003-2005. However, in 2007, the correlation between corn prices and crude oil prices is negative which causes the cointegrating relationship to be questionable. Soybean prices and crude oil prices show a much stronger correlation in 2007 than in 2003-2006. The correlation between soybean oil prices and crude oil prices is very strong in 2007. Both palm oil prices and sugar prices have a much stronger but opposite correlation with crude oil prices during 2007 than during 2003-2006.

The correlation coefficients were also calculated using the Fisher transformation (table 6). Since the correlation coefficient is not normally distributed and has non-constant variance, the Fisher transformation is generally used to normalize the distribution and stabilize the variance. It is also used to conduct tests of the correlation coefficients. The correlation between corn prices and crude oil prices is negative in 2007, yet insignificant. However, soybean prices have a very negative and significant correlation with crude oil prices in 2003-2006 and an extremely positive and significant correlation with crude oil prices in 2007. Both of the coefficients for soybean oil price and palm oil price in 2003-2006 are not significant. However, they both have a strong and significant correlation with crude oil prices in 2007. The cointegration tests did not reveal a cointegrating relationship between soybean oil prices/crude oil prices or palm oil prices/crude oil prices in the latter period, but this could be due to the low number of data points in 2007. Sugar prices have an extremely positive and significant correlation with crude oil prices in 2003-2006 and a high negative correlation in 2007. Yet, the cointegration tests did not indicate a cointegration relationship between sugar prices and crude oil prices in the earlier time period.

Results may indicate something about the relative levels of maturity of both the ethanol and biodiesel industries and speculation in the relevant agricultural commodities. The ethanol "boom" came first, and perhaps in 2007, the prices of corn and sugar are losing ground relative to crude oil prices as speculative positions unwind. By contrast, a biodiesel "boom" is currently underway, and we see the prices of biodiesel feedstocks becoming significantly positively correlated with crude oil prices in 2007.

Due to some unclear findings based on the joint analysis of the cointegration tests and correlation coefficients, further analysis needs to be conducted. Specifically, tests for parameter constancy need to be performed to analyze possible structural change in the data set. Hansen and Johansen (1999) suggest several tests for parameter constancy in cointegrated VAR models, including the forward and backward recursive tests. These tests examine the constancy of the long-run parameters in the model using recursively estimated eigenvalues. Recursive estimation is based on successively estimating parameters and calculating the eigenvalues at each step (Hansen and Johansen, 1999). The recursive estimation is viewed as a misspecification test to detect parameter instability when there are no assumptions or prior knowledge regarding time dependencies or structural breaks in the parameters (Hansen and Johansen, 1999). Additionally, Hansen and Johansen (1999) note that the fluctuation test by Ploeberger et al. (1989) and the Lagrange Multiplier test by Nyblom (1989) can also be used to test for parameter constancy.

Therefore, the next step in this research is to test for parameter instability to determine if structural change occurred during the 2003-2007 time period.

CONCLUSION

As the renewable fuels industry continues to expand at a rapid pace, more and more businesses and individuals will become involved in this industry. Agricultural producers will experience direct impacts on their income levels as the demand for renewable fuel feedstocks expands. Many crop producers will benefit from an increased demand for their products, while livestock producers may face higher production costs as they compete for feedstocks. As the finite supply of fossil oil is continuously consumed and prices continue to soar, the production of renewable fuels becomes increasingly important for our country. The renewable fuels industry has the potential to positively affect many agents in the U.S economy. The growth of the industry has tremendous implications for agriculture and opens up many new opportunities for agricultural producers. However, these new opportunities introduce new sources of risk as the market prices of agricultural commodities may become more dependent on fossil energy prices. A thorough understanding of the interrelationships among the prices of agricultural commodities and fossil fuel prices is essential for producers and policy makers to make informed decisions.

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Figure 1. Crude Oil Price Series

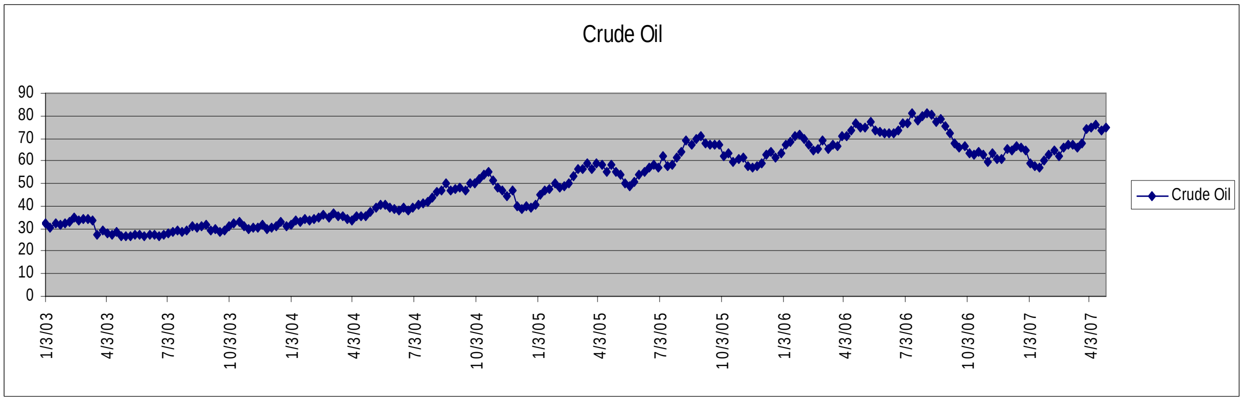

Figure 2. Corn Price Series

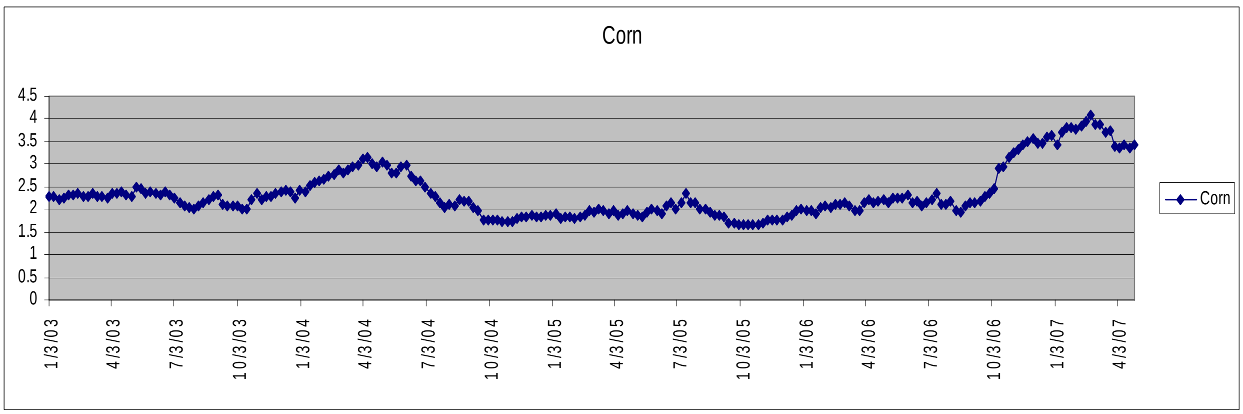

Figure 3. Soybean Oil Price Series

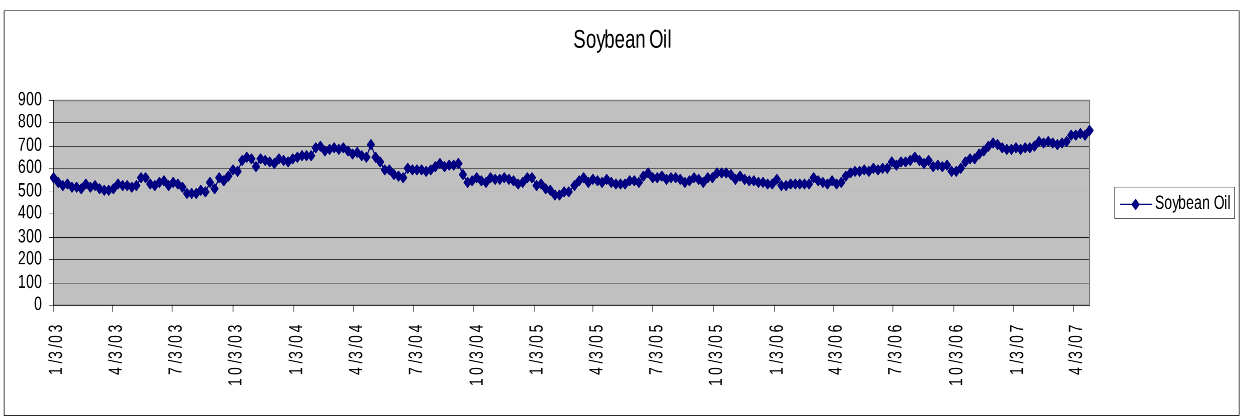

Figure 4. Soybean Price Series

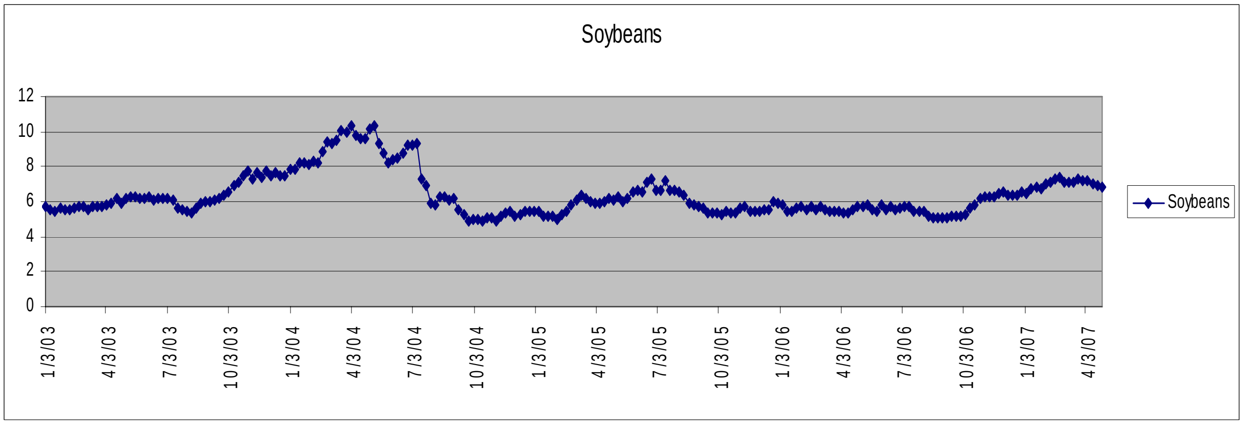

Figure 5. Sugar Price Series

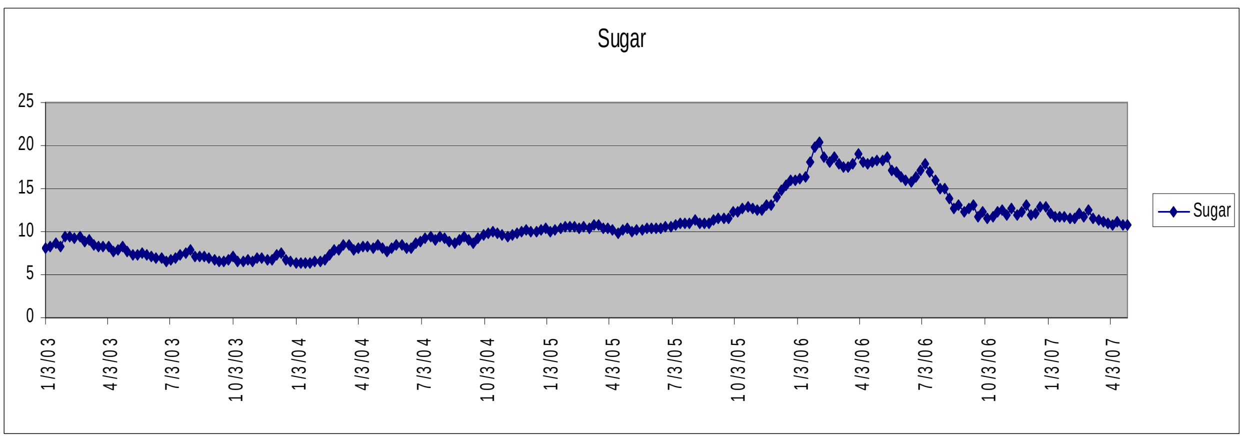

Figure 5. Palm Oil Price Series

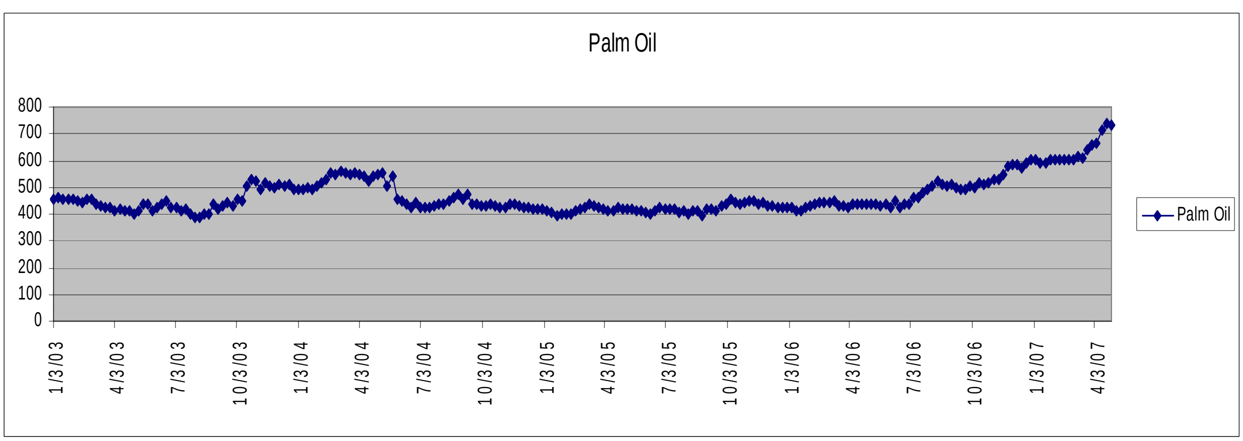

Table 1. **ADF Unit Root Tests (Variables in Levels)**

ADF unit root tests (variables in levels)

Variables	ADF
Crude Oil	-2.926
Corn	-1.102
Soybeans	-2.146
Sugar	-1.169
Soybean Oil	-1.611
Palm Oil	0.214

Critical Values: -4.00 (1%), -3.43 (5%), -3.14 (10%)

Table 2. ADF Unit Root Tests (Variables in First Differences)

ADF unit root tests (variables in first differences)

Variables	ADF
Crude Oil	-15.075
Corn	-13.364
Soybeans	-11.477
Sugar	-14.396
Soybean Oil	-16.568
Palm Oil	-13.010

Critical values are the same as in Table 1.

Table 3. Selection of Optimal # of Cointegrating Vectors for 2003-2005 Time Period

2003-2005	Ho:r cointegration vectors	L-Max	L-Max 90
Corn	0	5.41*	10.60
	1	0.52	2.71
Soybeans	0	5.01*	10.60
	1	0.80	2.71
Soybean Oil	0	4.22*	10.60
	1	0.69	2.71
Palm Oil	0	3.83*	10.60
	1	0.40	2.71
Sugar	0	5.95*	10.60
	1	2.41	2.71

*fail to reject Ho at first occurrence of L-Max < L-Max 90

Table 4. Selection of Optimal # of Cointegrating Vectors for 2006-2007 Time Period

2006-2007	Ho:r cointegration vectors	L-Max	L-Max 90
Corn	0	15.66	10.60
	1	1.32*	2.71
Soybeans	0	10.88	10.60
	1	2.52*	2.71
Soybean Oil	0	3.43*	10.60
	1	0.13	2.71
Palm Oil	0	4.52*	10.60
	1	1.55	2.71
Sugar	0	4.81*	10.60
	1	0.49	2.71

*fail to reject Ho at first occurrence of L-Max < L-Max 90

Table 5. Correlation Coefficients

	2003-2006	2007
Corn / Crude Oil	0.0651	-0.2365
Soybeans / Crude Oil	0.1009	0.2761
Soybean Oil / Crude Oil	-0.0042	0.6056
Palm Oil / Crude Oil	-0.0483	0.2906
Sugar / Crude Oil	0.2453	-0.4628

Table 6. Fisher's Transformation

	2003-2006	p-value	2007	p-value
Corn / Crude Oil	-0.1893*	0.0060	-0.1764	0.5542
Soybeans / Crude Oil	-0.4269*	<.0001	0.6870**	0.0052
Soybean Oil / Crude Oil	0.0644	0.3547	0.8143*	0.0002
Palm Oil / Crude Oil	-0.0215	0.7580	0.9082*	<.0001
Sugar / Crude Oil	0.8698*	<.0001	-0.6894*	0.0050

*significant at the .05 level

**significant at the .10 level