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The Relationship between Oil, Exchange Rates, and Commodity Prices

Ardian Harri, Lanier Nalley, and Darren Hudson

Exchange rates have long been thought to have an important impact on the export and import of goods and services, and, thus, exchange rates are expected to influence the price of those products that are traded. At the same time, energy impacts commodity production in some very important ways. The use of chemical and petroleum derived inputs has increased in agriculture over time; the prices of these critical inputs, then, would be expected to alter supply, and, therefore, the prices of commodities using these inputs. Also, agricultural commodities have been increasingly used to produce energy, thereby leading to an expectation of a linkage between energy and commodity markets. In this paper, we examine the price relationship through time of the primary agricultural commodities, exchange rates, and oil prices. Using overlapping time periods, we examine the cointegration relationship between prices to determine changes in the strength of the linkage between markets through time. In general, we find that commodity prices are linked to oil for corn, cotton, and soybeans, but not for wheat, and that exchange rates do play a role in the linkage of prices over time.

Key Words: cointegration, commodity prices, crude oil, exchange rates

JEL Classifications: C32, L71, Q11, Q40

Related Literature

Existing literature on crude oil's effect on commodity prices is thin, but several seminal articles highlight the underlying relationship between the two. Campiche et al. (2007) examined the covariability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices from 2003 to 2007 using a vector error correction model. Their cointegration results indicate that corn and soybean prices were cointegrated with crude oil price during the 2006–2007 time frame but not during the 2003–2005 period. Further results from the same study indicate that crude oil prices do not adjust to changes in the corn and soybean market. The authors concluded from their analysis that soybean prices seemed to be more correlated (through the biodiesel market) to crude oil prices than corn prices. A similar study conducted by Yu et al. (2006) analyzed the cointegration and causality of higher crude oil prices on the price and demand for vegetable oils. They conclude that the influence of shocks in crude oil prices on the variation in vegetable oil prices is relatively small, which appears to reflect results in Zhang and Reed (2008).

Another link between petroleum and commodity prices put forth by Abbot et al. (2008) is the relationship between rising crude oil prices and an increase in U.S. current account deficit.

Ardian Harri is assistant professor, Mississippi State University, Starkville, MS; Lanier Nally is assistant professor, University of Arkansas, Fayetteville, AR; and Darren Hudson is professor and Larry Combest Chair of Agricultural Competitiveness, Texas Tech University, Lubbock, TX.

A byproduct of an increasing current account is a depreciating currency which makes exports more attractive and imports less attractive (exchange rate effects). Since early 2004, crude oil prices have steadily increased and the U.S. dollar has simultaneously decreased in value relative to most other high and low-income countries' currencies. Both of these factors have resulted in higher corn prices in the U.S., as the decreased dollar has resulted in cheaper corn exports in places like China and India. Because of this, corn exports have not decreased even as corn prices continue to rise.

Like Abbott et al. (2008), other studies (Hanson et al., 1993; Schnept, 2008; Trostle, 2008) all highlight the effects of changing crude prices on exchange rates, which "trickle down" to commodity prices. Nevertheless, a comprehensive evaluation of the relationship between exchange rates, oil, and commodity prices has not been conducted. Changes in these relationships have implications for risk management strategies and may affect longer term policy prescriptions for agriculture.

Following the literature, one can conceptualize the linkages between oil, exchange rates, and commodity prices as in Figure 1. Here, we expect the "trickle down" effect of oil on commodity prices through exchange rates. The open question is whether exchange rates affect oil. It is reasonable to expect that a dollar-denominated asset like oil is affected by dollar exchange rates. Direct empirical evidence of this hypothesis is, however, more scant than one might expect. Finally, oil affects commodity production (and, thus, price) through input prices. But, increasingly, oil potentially affects at least some agricultural products through competition in output markets (biofuels). Thus, we anticipate a direct linkage between oil and commodity prices in addition to the indirect effect through exchange rates.

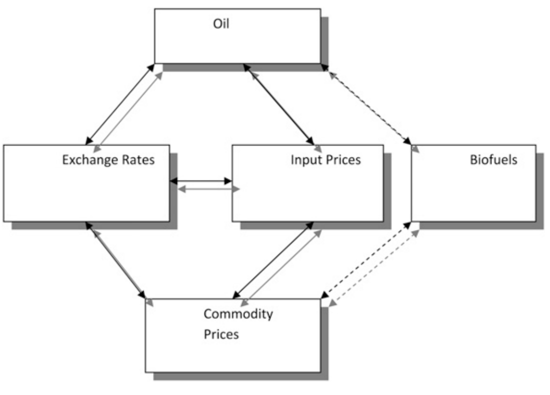

Figure 1. Expected Linkages Between Oil, Exchange Rates, and Commodity Prices

Data and Methods

The Johansen (1992) model is considered to examine the relationship between exchange rates, crude oil prices, and agricultural crop prices. The model is a p-dimensional, k^{th} order VAR-model, written in error-correction form

$$(1) \qquad \Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \varepsilon_t$$

where X is a vector of exchange rates and prices, and Γ_1 through Γ_{k-1} $(p \times p)$ and Π $(p \times p)$ are parameters to be estimated for some $r = 1, \ldots, p$. The errors ε are assumed to be independent and Gaussian with mean zero and covariance matrix Ω.

The rank of matrix Π is of interest with regard to the long-run cointegrating relationships between variables in the model. Engle and Granger (1987) provide a general definition of cointegration: if all the variables in X_t are integrated of order d, and there exist a cointegrating vector $\beta \neq 0$ such that $\beta' X_t$ is integrated of order d–r, then the processes in X_t are cointegrated of order CI(d,r).

If the rank of Π is equal to p then all variables in X are stationary. If the rank of Π equals zero, model (1) reduces to a differenced vector time series model implying that no cointegration relationships exist among variables in X. If the rank of Π is greater than zero but less than p, there exist two matrices α $(p \times r)$ and β $(p \times r)$ such that $\Pi = \alpha\beta'$. β consists of r cointegrating vectors representing the long-run relationship between the variables in X while the α's are the adjustment parameters following a deviation from the long-run relationships (Johansen and Juselius, 1990). Under the assumption of cointegration of order r model (1) can be written as

$$(2) \qquad \Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t$$

The model in (2) has the property that under suitable conditions on the parameters the process is non-stationary, ΔX_t is stationary, and $\beta' X_t$ is stationary. See Johansen (1992, 1995).

The Augmented Dickey-Fuller Test (ADF) proposed by Dickey and Fuller (1979, 1981) is used to test the stationarity of each variable in X and ΔX. Following Johansen (1992), to determine if cointegration relationships exist between the variables, first the lag length (k) is determined and then cointegration rank (r) is determined. To determine the lag length the Akaike Information Criterion (AIC) (Akaike, 1974, 1987) Corrected Akaike Information Criterion (CAIC) (Bozdogan, 1987) and the Schwarz Bayesian Criterion (SBC) (Schwarz, 1978) (also known as BIC) are used. To determine the cointegrating rank Johansen (1992) proposes two possible tests: the λmax test and the trace test.[1] The $\lambda_{\max}$ test is obtained using $\lambda_{\max} = -T\ln(1-\lambda_{r+1})$ where the λi 's are the eigen values of the matrix $\Pi = \alpha\beta'$. The idea behind the $\lambda_{\max}$ test is that if the $(r+1)^{\text{th}}$ eigen value is accepted to be zero than the smaller eigen values can also be accepted to be zero. This test is a test of whether there exist $r+1$ cointegrating vectors against r cointegrating vectors. The trace test is obtained using $\lambda_{\text{trace}} = -T\sum_{i=r+1}^{p}\ln(1-\lambda_i)$ where only the $p-r$ smallest non-zero eigenvalues, $\lambda = (\lambda_{r+1}, \ldots, \lambda_p)$, are used in the calculation of the test statistic. The null hypothesis for the trace test is that there are $(p-r)$ cointegrating vectors. The trace test is used in this research since it provides a more consistent way of determining the cointegration order (Johansen, 1992; Johansen and Juselius, 1992).

Exchange rate data, measured as a trade weighted average of the value of the U.S. dollar against the currencies of a group of major U.S. trading partners, were obtained from the Federal Reserve Economic Data database. Futures price data for crude oil and several agricultural commodities including corn, soybeans, soybean oil, cotton and wheat were obtained from Commodity Research Bureau. Data are monthly observations for the period January 2000 to September 2008.

[1] Cointegrated ADF (CADF) test of Engle and Granger (1987) is also an alternative test for cointegration.

Results

Results of the ADF tests for unit roots confirm the lack of stationarity in levels (Table 1) for all series. ADF tests on the differenced data confirm that all differenced series are stationary (Table 2). We then check for the presence of cointegrating relations between crude oil and agricultural commodities corn, soybeans, soybean oil, cotton and wheat. AIC and SBC criteria are used to first determine the lag length for the pairwise relations. We find that lag length is four for corn, soybeans and soybean oil and two for cotton and wheat. This implies longer dynamic relations between crude oil and corn, soybeans and soybean oil than between crude oil and cotton and wheat. In testing for cointegrating relations, we split the data sample into the before and after samples using as a separating date January 1, 2004. We then recursively move the separating date forward one month at a time. These recursive tests confirm that a consistent cointegrating relation exists between crude oil and corn, soybeans and soybean oil starting in April 2006 and between crude oil and cotton starting in June 2004. The earlier date for cotton may be a result of the relative importance of total petroleum-based inputs used in production relative to the other

Table 1. ADF Unit Root Tests (variables in levels)

	Dickey Fuller Unit Root Tests			
Variable	Rho	Prob < Rho	Tau	Prob < Tau
FX rate	−0.66	0.9132	−0.36	0.9107
Crude oil	−1.77	0.8025	−0.69	0.8435
Corn	−1.74	0.8066	−0.54	0.8782
Soybeans	−5.44	0.3864	−1.44	0.5601
Soybean oil	−4.28	0.5018	−1.33	0.6119
Cotton	−8.51	0.183	−2.01	0.2836
Wheat	−2.51	0.7125	−0.94	0.7733

Table 2. ADF Unit Root Tests (variables in first differences)

	Dickey Fuller Unit Root Tests			
Variable	Rho	Prob < Rho	Tau	Prob < Tau
FX rate	−103.6	0.0001	−6.78	<0.0001
Crude oil	−94.64	0.001	−5.78	<0.0001
Corn	−89.18	0.001	−6.29	<0.0001
Soybeans	−103.47	0.0001	−6.45	<0.0001
Soybean oil	−84.61	0.001	−5.47	<0.0001
Cotton	−104.43	0.0001	−7.01	<0.0001
Wheat	−118.57	0.0001	−7.36	<0.0001

crops. In the case of crude oil and wheat, while at several points in time we fail to reject the presence of a cointegrating relation, these findings are not consistent. In addition, the time periods when we fail to reject the presence of cointegration occur before April 2005. Therefore, we conclude that in the most recent periods no cointegrating relation exists between crude oil and wheat. This is likely because in recent years, wheat prices have been heavily influenced by weather events, meaning less influence of input prices (as well as the fact that wheat is not significantly used in ethanol production). As a result, wheat is excluded from further analysis.

Next, we test for the presence of cointegrating relations between crude oil, corn and exchange rates. A lag length of four was determined using the AIC criterion. We then perform the similar recursive procedure as in the case of pairwise tests above. A cointegrating relation is found to exist beginning in April 2006. Results of the Johansen's trace test for cointegration are reported in Table 3. Cointegration tests are reported for two cases, one where a constant is included in the error correction component (also referred to as the cointegrating space) but not in the autoregressive component of the VAR model. The other case allows for a constant to be included in the autoregressive component of the VAR and not in the error correction component. Trace tests for both cases conclude that there are two cointegrating vectors between crude oil, corn and exchange rates. A χ^2 test rejects the case where a constant is included in the error correction component but not in the autoregressive component of the VAR; therefore the model with a constant in the autoregressive component only is estimated. Having found a cointegrating relation, we fit the error correction model in (2) to the system of crude oil, corn and exchange rates. Table 4 reports the parameter estimates for the error correction model. Panel (a) of Table 4 reports the two cointegrating vectors and adjustment parameters. The speed of adjustment of the price of corn, $\hat{\alpha}_3 = 0.948$, to the first cointegrating relation is much stronger than to the second. Therefore, we interpret this cointegrating relation as the one between corn, crude oil and the exchange rate. We interpret the second cointegration relation as a relation between the exchange rate and crude oil. The graphs of the cointegration vectors against the price series in Figures 2 and 3 confirm these interpretations. Panel (b) of Table 4 reports the $\Pi = \alpha\beta'$ parameter estimates while

Table 3. Results of Johansen Trace Cointegration Test for Crude Oil, Corn and the Exchange Rate

		Constant in ECM*	Constant in Process	Constant in ECM*	Constant in Process
H0:	H1:	Yes	No	No	Yes
Rank = r	Rank > r	Trace	5% Critical Value	Trace	5% Critical Value
0	0	54.1281	34.8	41.5007	29.38
1	1	29.6566	19.99	18.7282	15.34
2	2	7.2426	9.13	1.4602	3.84
Hypothesis Test for Including a Constant in the Process but not in ECM*					
H0:	Yes	No	Chi-Square	Pr > ChiSq	
H1:	No	Yes	5.78	0.0162	

* This is the error correction component of the vector autoregression model.

Table 4. Parameter Estimates of the Error Correction Model for Crude Oil, Corn and the Exchange Rate

a) Cointegrating Vectors $\hat{\beta}'$ and Adjustment Coefficients α

	FX	Crude Oil	Corn	FX		$\hat{\beta}_1'X$	$\hat{\beta}_2'X$
$\hat{\beta}_1'$	1.643	1	−0.331	Crude Oil	$\hat{\alpha}_1$	0.012	0.007
$\hat{\beta}_2$	6.112	1	0.099	Corn	$\hat{\alpha}_2$	−0.12	−0.034
					$\hat{\alpha}_3$	0.948	−0.175

b) Parameter Estimates $\hat{\Pi} = \hat{\alpha}\hat{\beta}'$

Variable	ΔFX	ΔCrude Oil	ΔCorn
FX_{t-1}	0.47	0.086	0.003
Crude oil_{t-1}	−2.27	−0.458	0.006
$Corn_{t-1}$	−9.21	−0.811	−0.488

c) Short Run Parameter Estimates

Variable/Equation	ΔFX	ΔCrude Oil	ΔCorn	Misspecification Tests			
Constant	−57.91**	271.658**	1205.421**		R^2	Normality	ARCH
	(12.412)[a]	(81.587)[a]	(534.342)[a]				
ΔFX_{t-1}	−0.629**	4.082**	28.324**	ΔFX	0.78	1.08[b]	0.61[c]
	(0.255)[a]	(1.676)[a]	10.977)[a]				
ΔCrude oil_{t-1}	−0.071*	0.72**	4.308**	ΔCrude oil	0.76	0.66[b]	0.25[c]
	(0.038)[a]	(0.246)[a]	(1.613)[a]				
$\Delta Corn_{t-1}$	−0.010**	0.0358	0.398**	ΔCorn	0.67	0.94[b]	0.18[c]
	(0.003)[a]	(0.022)[a]	(0.142)[a]				
ΔFX_{t-2}	−0.872**	0.693	−13.991				
	(0.224)[a]	(1.472)[a]	(9.643)[a]				
ΔCrude oil_{t-2}	−0.053	0.007	−2.938*		DW		
	(0.035)[a]	(0.227)[a]	(1.487)[a]				
$\Delta Corn_{t-2}$	0.009*	−0.034	0.307*	ΔFX	2.55		
	(0.004)[a]	(0.027)[a]	(0.178)[a]				
ΔFX_{t-3}	−0.396*	0.276	10.19	ΔCrude oil	2.06		
	(0.202)[a]	(1.33)[a]	(8.709)[a]				
ΔCrude oil_{t-3}	0.053	−0.414*	3.328**	ΔCorn	2.38		
	(0.032)[a]	(0.212)[a]	(1.385)[a]				
$\Delta Corn_{t-3}$	0.012**	−0.038**	0.766**				
	(0.005)[a]	(0.03)[a]	(0.194)[a]				

[a] Standard errors are in parentheses.
[b] These are Chi-Square values. The 5% critical value is 5.99.
[c] These are F-values. The 5% critical value is 2.69.
** Denotes significance at the 5% level and * at the 10% level.

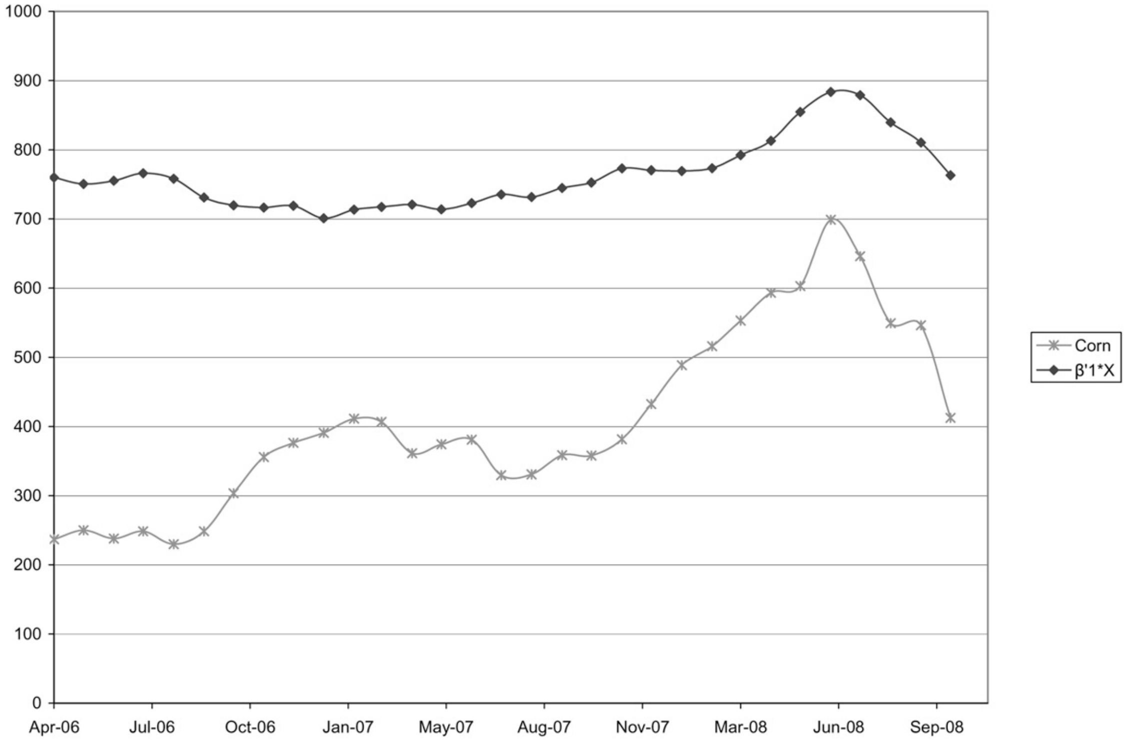

Figure 2. Graph of the First Cointegrating Vector and Corn Price

panel (c) reports the parameter estimates of the short run relations between corn, crude oil and exchange rate as well as several mis-specification tests. Based on these tests we fail to reject the assumption of normality, homoscedasticity, and no autocorrelation in the residuals for the three equations. Finally, tests of weak exogeneity show that the null hypothesis cannot be rejected at the 5% level of significance for crude oil while it is rejected[2] for corn and the exchange rate. The fact the crude oil is found to be exogenous means that while it Granger-causes corn prices and exchange rate, the corn prices and exchange rate do not Granger-cause oil prices. So, shocks to the oil prices are transferred to the corn prices and exchange rate but not vice-versa.

Finally we investigate the presence of cointegrating relations between several agricultural commodities like corn, soybeans, soybean oil and cotton, and crude oil and exchange rate. For a lag length of two, only one cointegrating relation is found. The reason for only one cointegrating relation may be the small data sample consisting of only 31 observations. We do find more than one cointegrating relation with longer data series, but we believe these relations exist between the agricultural series. We restrict our analysis here to the period since April 2006 since that is the earliest period when a cointegrating relation between corn and crude oil was found. The results of the cointegration tests and estimation for all the series are reported in Tables 5 and 6. However, given the short data series these results should be interpreted with caution.

Conclusions

The results presented here provide clear evidence that the strength of the relationship between corn and oil, which is indicative of the growing use of corn for ethanol, has increased over time. At the same time, greater use of petroleum-based inputs in both corn and cotton

[2] The weak exogeneity, however, is rejected at the 10% level even for crude oil.

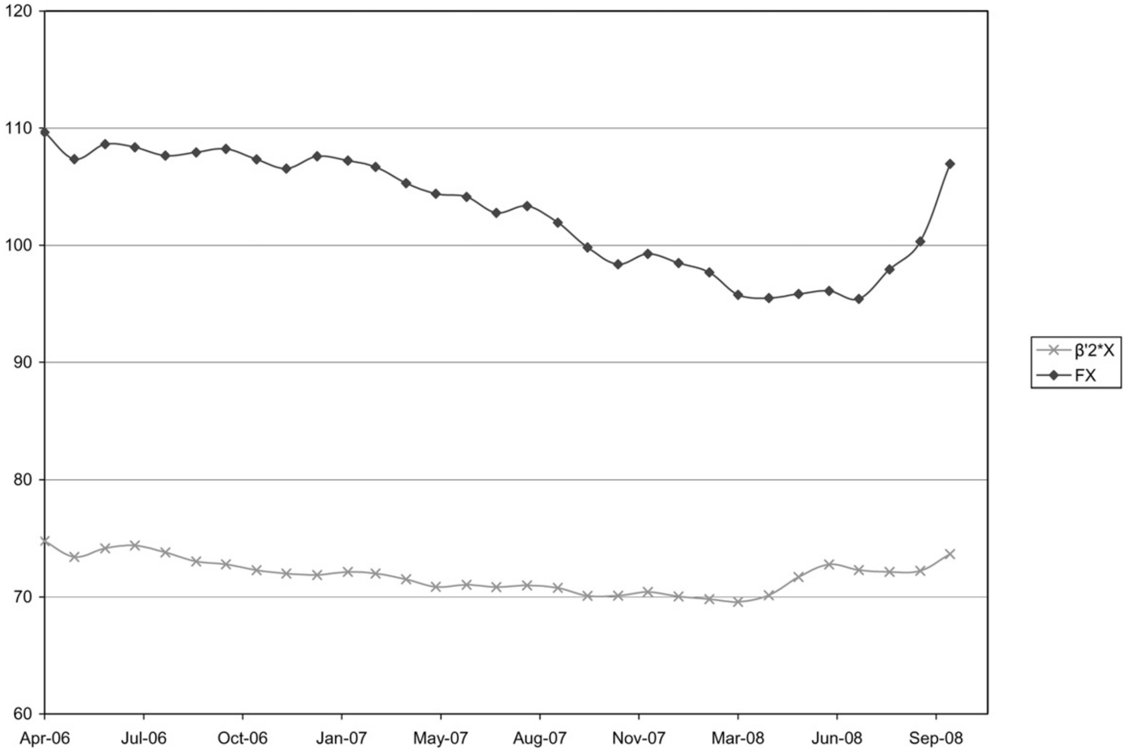

Figure 3. Graph of the Second Cointegrating Vector and Exchange Rate

also link these markets. Equally important is the finding of the relationship between exchange rates, corn, and oil, suggesting that all of these prices are interrelated. There are two main implications resulting from the findings of this research. The first implication has to do with the effect of the changes in the relationship between crude oil and corn prices in risk

Table 5. Results of Johansen Trace Cointegration Test for Crude Oil, Corn, Soybeans, Soybean Oil, Cotton and the Exchange Rate

		Constant in ECM*	Constant in Process	Constant in ECM*	Constant in Process
H0:	H1:	Yes	No	No	Yes
Rank = r	Rank > r	Trace	5% Critical Value	Trace	5% Critical Value
0	0	112.4783	101.84	109.9446	93.92
1	1	68.0078	75.74	66.3408	68.68
2	2	42.8745	53.42	41.2092	47.21
3	3	22.759	34.8	22.5543	29.38
4	4	8.2615	19.99	8.2596	15.34
5	5	3.8008	9.13	3.7991	3.84

Hypothesis Test for Including a Constant in the Process but not in ECM*

H0:	Yes	No	Chi-Square	Pr > ChiSq
H1:	No	Yes	1.67	0.893

* This is the error correction component of the vector autoregression model.

Table 6. Parameter Estimates of the Error Correction Model for Crude Oil, Corn, Soybeans, Soybean Oil, Cotton and the Exchange Rate

a) Cointegrating Vectors and Adjustment Coefficients α

Constant	FX	Crude Oil	Corn	Soybeans	Soybean Oil	Cotton
−109.934	1	−0.035	−0.016	0.018	0.200	−0.144
	−0.225	−0.158	−32.497	−67.851	−1.892	0.100

b) Parameter Estimates

Variable	Constant	FX	Crude Oil	Corn	Soybeans	Soybean Oil	Cotton
FX_{t-1}	24.764	−0.225	0.008	0.004	−0.004	−0.045	0.032
Crude oil_{t-1}	17.414	−0.158	0.006	0.003	−0.003	−0.032	0.023
$Corn_{t-1}$	3572.557	−32.497	1.146	0.526	−0.598	−6.506	4.667
$Soybeans_{t-1}$	7459.141	−67.851	2.394	1.098	−1.249	−13.585	9.743
Soybean oil_{t-1}	207.972	−1.892	0.067	0.031	−0.035	−0.379	0.272
$Cotton_{t-1}$	−11.03	0.100	−0.004	−0.002	0.002	0.020	−0.014

c) Short Run Parameter Estimates

Variable/ Equation	ΔFX	ΔCrude Oil	ΔCorn	ΔSoybeans	ΔSoybean Oil	ΔCotton
ΔFX_{t-1}	0.01	1.201	23.142**	48.62	1.417**	0.724
	(0.356)	(1.711)	(8.599)	(14.956)	(0.688)	(0.816)
ΔCrude oil_{t-1}	−0.051	0.551*	−2.760*	−3.719	−0.148	−0.043
	(0.032)	(0.297)	(1.495)	(2.60)	(0.12)	(0.142)
$\Delta Corn_{t-1}$	0.00001	0.040	−0.006	−0.257	0.001	−0.017
	(0.01)	(0.049)	(0.246)	(0.429)	(0.02)	(0.023)
$\Delta Soybeans_{t-1}$	−0.0002	−0.051	−0.577**	−0.244	−0.02	0.022
	(0.009)	(0.045)	(0.225)	(0.391)	(0.018)	(0.021)
ΔSoybean oil_{t-1}	−0.205	1.858	31.152**	46.921	1.883**	0.775
	(0.262)	(1.258)	(6.321)	(10.994)	(0.506)	(0.60)
$\Delta Cotton_{t-1}$	−0.035	−0.161	0.189	−1.565	−0.014	−0.15
	(0.079)	(0.378)	(1.898)	(3.30)	(0.152)	(0.18)

Table 6. Continued.

	Misspecification Tests			
	R^2	Normality	ARCH	DW
ΔFX	0.41	32.94	0.06	1.81
ΔCrude oil	0.46	6.77	0.27	1.95
ΔCorn	0.54	10.34	1.28	2.03
ΔSoybeans	0.63	17.50	0.15	1.98
ΔSoybean oil	0.55	6.52	0.16	1.89
ΔCotton	0.50	2.30	0.96	2.08

[a] Standard errors are in parentheses.
** Denotes significance at the five percent level and * at the ten percent level.

management strategies for corn producers. Changes in the relationship between the output (corn) prices and input prices (through crude oil) implies that the conventional strategies of managing output price risk may not work as well as before. Therefore, the identification of the changes in the relationship between these prices suggests further research is needed to identify appropriate marketing strategies that can be used for risk management.

The second implication based on the findings of this research is related to policy actions with respect to biofuels and particularly ethanol from corn. Changes in the relationship between crude oil and corn prices are observed around the time when the renewable fuel standard (RFS) mandates, and in particular corn ethanol production mandates, were raised following the Energy Policy Act 2005 (Anderson and Coble, 2009). Thus, policy actions that result in maintaining or changing the current RFS mandates need to take into account their effect on these markets.

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