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The Impact of the Oil Sector on Commodity Prices: Correlation or Causation?

Sayed H. Saghaian

The interconnections of agriculture and energy markets have increased through the rise in the new biofuel agribusinesses and the oil–ethanol–corn linkages. The question is whether these linkages have a causal structure by which oil prices affect commodity prices and through these links, instability is transferred from energy markets to already volatile agricultural markets. In this article, we present empirical results using contemporary time-series analysis and Granger causality supplemented by a directed graph theory modeling approach to identify the links and plausible contemporaneous causal structures among energy and commodity variables. The results show that although there is a strong correlation among oil and commodity prices, the evidence for a causal link from oil to commodity prices is mixed.

Key Words: ethanol prices, crude oil prices, corn prices, soybean prices, wheat prices, causal structure

JEL Classifications: Q11, Q13, Q42, Q48

We recently observed several occurrences of major importance to the agricultural sector simultaneously: the extreme price hikes in the energy sector, the extreme commodity price variability with wider variation and higher averages compared with the past, and the continuing global financial and economic crisis. Last year's farm income was the highest recorded in the history of the U.S. Within this context, the purpose of this article is to examine the extent of energy and agricultural sectors' interlinkages and their interconnections, and the causal structure of the impact of crude oil and ethanol prices on commodity prices.

Ethanol was introduced in the early 1980s as a transportation fuel to be blended with gasoline to increase its octane level. Later the role of ethanol was shifted to become an "oxygenate" to help gasoline burn more efficiently through several government mandates. The maximum amount of ethanol that could currently be blended stands at the 10% level. With the current U.S. consumption of gasoline being approximately 140 billion gallons annually, the maximum amount of ethanol blended as E10 is approximately 14 billion gallons (Taheripour and Tyner, 2008).

Ethanol production has increased tremendously in recent years. There were only approximately 50 ethanol plants in the U.S. in the late 1990s, producing approximately one billion gallons annually. The Renewable Fuels Standard Act, which was passed in 2005, targeted 7.5 billion gallons of ethanol production by the year 2012. Additionally, Congress passed another energy bill in 2007, doubling the Renewable Fuels Standard by the year 2015 to billion gallons.

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A large portion of the growth in corn demand is associated with growth in ethanol production, because most ethanol in the U.S. is made from corn. Higher gasoline prices make ethanol production more viable, increasing the supply of ethanol. More ethanol plants and production translates into more demand for corn, which in turn increases corn prices, *ceteris paribus* (assuming all other things being equal).[1] Higher corn prices make corn more profitable to grow, causing some farmers to shift from other crops to corn production. This will also push food, seed, and industrial users to shift from corn to other commodities, increasing their prices. The objective of this research is to identify the nature of these links and address how variables such as crude oil and ethanol prices impact prices of different commodities such as corn, soybeans, and wheat.

Literature Review

Agricultural economists have long studied factors that move commodity prices over time. In the past they were particularly interested in the effects of exchange rate policy on agricultural prices. Schuh (1974) argued that changes in U.S. macro policy could affect the value of dollar, which in turn impacts the competitiveness of U.S. agricultural commodities in the world markets through price changes. The interest in this topic was later heightened as a result of the "overshooting hypothesis" (Frankel, 1986; Saghaian, Reed, and Marchant, 2002a). Agricultural price overshooting also affects farm prices and income and could partially explain the observed price variability. For many years, much attention was given to the role of exchange rates and monetary change and its transmission of macro changes to agricultural prices. However, nowadays, the links among oil, ethanol, and commodity prices and the nature of relationships between energy and agricultural sectors have become an important issue.

One concern is that the integration of agricultural and energy markets could add to the already volatile agricultural prices. According to a report by the Food and Agriculture Organization of the United Nations, food prices increased by almost 40% in 2007 and continued increasing sharply in 2008 (Rosegrant, 2008). Taheripour and Tyner (2008) showed that a large share of the corn price hikes is the result of the increase in the oil prices. Rosegrant (2008) shows that 30% of the increase in grain prices is estimated to be the result of the increased biofuel demand with corn prices having the sharpest increase with 39% in real prices.

In the most recent issue of *Choices Magazine*, Irwin and Good (2009), who examined changes in the agricultural commodity prices, showed recent commodity price changes have higher averages and wider variations than previous price changes. In the same issue, von Braun and Torero (2009), who investigated the commodity price spike of 2007–2008, looked at the role of trade policy changes such as the rise in export barriers and the fall of import barriers as well as the role of speculative activity in the observed price spike in the commodity markets.

Baffes (2007) showed among nonenergy commodities, oil price changes have the highest pass-through to food commodities and fertilizers. von Braun et al. (2008) found high energy prices have increased the costs of transportation and agricultural inputs such as fertilizer and pesticides, making agricultural production more expensive. Morehart (2009) investigated the impact of macroeconomic policy on land values. He found that land values are also highly sensitive to macroeconomic conditions. Muhammad and Kebede (2009) argued the emerging ethanol market has integrated oil and corn prices in such a way that the agricultural sector is now importing instability from the oil sector.

Conley and George (2008) argue that continuous growth of biofuel industries and the increased demand for corn have important implications for the managers of grain farms and agribusinesses. They conclude that factors such as government macro policies regarding ethanol would cause structural changes not only in the U.S. production and marketing of corn, but also other crops such as soybeans, wheat, and

[1] As pointed out by an anonymous reviewer, for 2009–2010 marketing year, increased demand for corn for ethanol was more than offset by a slight increase in acreage, which led to lower prices. Prices also declined from July 2008 to August 2009 along with declining acreage and increasing ethanol demand.

possibly even cotton as a result of the rotational nature of crop production.

Siebert, Hagerman, and Park (2008) argue that some farmers, who have been interested in ethanol production, have made unnecessary very large downstream investments in the past. They discuss investment techniques that could improve and enhance methods of investing in the production of ethanol. Obviously these issues are of paramount importance for the future feasibility of ethanol production and profitability of farm operations in the U.S.

Econometric Model Development and Empirical Results

Most agricultural economists are comfortable with a supply–demand framework in commodity price analysis and such analyses are quite common in the literature. This is natural because there are strong conceptual foundations linking economic variables to producer and consumer decisions. These foundations have been used for decades and are well understood and accepted in the profession. However, economic theory does not provide sufficient information about the causal structures among energy and commodity prices.

The challenge in the analysis of macroeconomic linkages to agriculture is to eliminate the simultaneous (supply–demand) linkages among commodities so that the relationship among individual commodity prices and macroeconomic variables can be isolated. If daily or weekly grain prices are dominated by revised storage estimates, crop estimates, and weather fears, it is difficult to isolate the effects of other variables such as crude oil prices or ethanol policy changes. Examining the causal structure of energy and commodity prices can show how they react to crude oil shocks and increased ethanol prices while also taking into consideration the simultaneity among the prices.

There have been numerous theoretical and empirical estimates of the effects of macroeconomic variables on commodity prices. These analyses have progressively improved as a result of theoretical refinements and more powerful time-series techniques (vector autoregressive and vector error correction models) that provide better adjustments for nonstationarity and long run relationships among variables (Crane and Nourzad, 1998; Schmidt, 2000).

Recent advances in time-series econometric techniques allow us to use a reduced form of commodity price equations that collapses the structural simultaneity of commodity models and isolates underlying macroeconomic relationships. The tools are powerful enough that linkages among commodities can be viewed by predicting forward movements in endogenous variables (commodity prices) using time-series techniques.

The empirical model underlying this study is built on the existing literature (Saghaian, Ozertan, and Spaulding, 2008). We include monthly prices of five variables: corn prices per bushel, soybean prices per bushel, wheat prices per bushel along with crude oil and ethanol prices per gallon. Second, we build on Robertson and Orden's (1990) cointegration approach by using Johansen and Juselius' (1992) method of estimation. Empirically, the first difference in each variable is represented as a function of its own lagged value, the lagged values of the other variables, and the cointegration equation. Given the nature of the underlying data series, we conduct stationarity tests of the series using the augmented Dickey-Fuller test. Then, we perform a cointegration test to determine whether there exists a long-run relationship among the series in the system. Third, we specify a vector error correction model and conduct hypothesis testing within this framework. Finally, this is followed by Directed Graph analysis and Granger Causality tests to examine the causal structures among the variables.

Stationarity Testing

Monthly time-series data are collected from 1996:01–2008:12 for the variables. Commodity price data come from the Agriculture Statistics Board.[2] Oil and ethanol data come from the Economic Research Service, USDA, 2008.

[2] The assistance of Andrew Mohammad in providing the data used in this study is gratefully acknowledged.

Descriptive statistics of the variables can be found in Table 1.

Correlation Matrix

The correlation matrix of the five variables as shown in Table 2 indicates a high correlation of 89% between oil and ethanol price series. This is expected because oil and ethanol are nearly perfect substitutes. Also, there is a high correlation among the commodity prices: corn and soybeans 88%, corn and wheat almost 90%, and soybeans and wheat 83%.

An augmented Dickey-Fuller (ADF) test is used to determine the order of integration of each univariate series. This test involves running a regression of the first difference of the series against the series lagged one period, lag difference terms, and a constant. The results of the unit-root test are estimated by ordinary least squares and presented in Table 3. The second column of Table 3 summarizes the ADF test results for each original variable, whereas the third column presents the results for the first difference of each series.

Following Enders (1995) and Hendry's (1986) "General to Specific" procedure, we started with an overspecified ADF regression in which n was relatively large and then used a battery of lag length diagnostic tests to refine the specification for each univariate series. We use the Akaike Information Criterion (AIC) and Schwarz criterion to determine the appropriate lag specification (n). In general, the F-statistic of the ADF regression with $n = 2$ was statistically significant ($p < 0.01$) in each case. In general, partial t-statistics were not significantly different from zero beyond two lags. In each case, we failed to reject the null hypothesis of zero first-order autocorrelation at the 5% level of significance using the Durbin-Watson bound test.

As shown in Table 3, the ADF test statistics in absolute value for all series rose after first differencing (right-most column of Table 3). Thus, we are able to reject the null hypothesis and conclude that each series is stationary after first differencing. Based on this analysis, we use all data as an integrated process of order 1 or I (1).

Johansen's Cointegration Tests

Based on the ADF test, a vector error correction (VEC) model is more appropriate than a vector autoregression model to characterize the multivariate relationships among the eight series (Engle and Granger, 1987; Enders, 1995). Cointegration tests were performed using Johansen's method. The Johansen cointegration method is designed to determine the cointegrating rank, r, or the number of cointegrating vectors in the system using the likelihood ratio (LR) test (Holden and Perman,

Table 1. Descriptive Statistics of Variables in the Empirical Model

Variables	Mean	Standard Deviation	Minimum	Maximum
Corn[a]	2.56	0.87	1.53	5.48
Soybean[a]	6.43	1.97	4.09	13.30
Wheat[a]	3.81	1.52	2.13	10.00
Oil[b]	40.44	26.37	11.28	133.93
Ethanol[b]	1.58	0.57	0.90	3.58

[a] Dollars/bushel.
[b] Dollars/gallon.

Table 2. The Correlation Matrix of the Variables

Variables	Oil	Ethanol	Corn	Soybeans	Wheat
Oil	1				
Ethanol	0.89	1			
Corn	0.45	0.46	1		
Soybeans	0.49	0.46	0.88	1	
Wheat	0.67	0.64	0.9	0.83	1

Table 3. Augmented Dickey-Fuller (ADF)[a] Test Results

Variables	Test Results for Variables in Levels	Test Results for Variables after First-Differencing
Corn	−2.53	−6.02[b]
Soybean	−1.82	−8.67[b]
Wheat	−1.83	−8.65[b]
Oil	−2.53	−6.09[b]
Ethanol	−2.01	−9.80[b]

[a] In absolute value and compared with MacKinnon, Haug, and Michelis (1999) critical values.
[b] One percent significance level.

1994; Vickner and Davies, 2000). Theoretically, the rank, *r,* can be at most one less than the number of endogenous variables in the model. The LR test in our analysis determines if cointegrating vectors exist among the eight endogenous macroeconomic series.

Table 4 presents the results of cointegration tests for each commodity. Each cointegrating equation contains an intercept and a money supply slope coefficient. At the 1% level of significance for the trace test (Johansen and Juselius, 1992) and Max-Eigen statistics, we reject the null hypothesis that $r = 0$; thus, LR tests reveal there exists a stationary, linear combination among corn, soybean, wheat, oil, and ethanol series.

Vector Error Correction Model

The Johansen's cointegration test indicates that the series are cointegrated. Therefore, as discussed, the VEC model is appropriate for this study. In this model, the first difference of each variable is represented as a function of its own lagged values, the lagged values of the other variables, and the cointegrating equations.

In a VEC system, it is difficult to characterize the qualitative relationships among variables and the expected sign of the unknown parameters to be estimated. However, we expect the long-run equilibrium relationships to be positive in the case of the relationship among the commodity prices, oil prices, and ethanol prices because a rise in the crude oil and ethanol prices is expected to increase the level of commodity prices.

The speed of adjustment parameters represents overshooting parameters, indicating how quickly the system adjusts to its long-run equilibrium. We conjecture the speeds of adjustments to be negative because commodity prices must fall to re-establish the long-run equilibrium among the system variables. We expect with a rise in oil and ethanol prices, commodity prices initially overshoot beyond their long-run equilibrium levels and later move back to their long-run equilibrium levels.

Based on the cointegration test and standard multivariate time-series analysis diagnostics such as AIC and Schwarz Criterion, the VEC model is specified. The specification of the VEC model consists of five cointegrating equations and includes two lags with an intercept. Partial *t*-statistics were statistically insignificant for lag lengths greater than 2. As expected, we failed to reject the null hypothesis of zero first-order autocorrelation at the 5% level of significance using the Durbin-Watson bounds test. The results indicate there is statistically significant overshooting of each commodity price series. Overshooting of commodity prices could partially explain the high farm income in 2008.

Causality and Directed Graph

Any inference on the energy and commodity price causal structures requires a careful investigation of contemporaneous correlation among corresponding innovations. A formal test of contemporaneous causal structures was performed to capture those contemporaneous effects. The covariance matrix of the VEC model was used to investigate the causal relationships among the variables by directed acyclic graphs[3] (Bessler and Akleman, 1998; Saghaian, Hasan, and Reed, 2002b). An algorithm is used that first assigns undirected lines to all the nodes (variables) and then removes

Table 4. Johansen Cointegration Test Results[a]

Null Hypothesis[b]	Max-Eigen Statistic	5% Critical Value	Eigen Value
$r = 0$	35.16	33.88	0.20
$r \leq 1$	21.01	27.58	0.12
$r \leq 2$	12.95	21.13	0.08
$r \leq 3$	8.46	14.26	0.05
$r \leq 4$	4.63	3.84	0.03

[a] Max-Eigen statistic test indicates one cointegrating equation at the 5% level.
[b] r is the cointegrating rank.

[3] A directed graph is a picture representing the causal flow among a set of variables called nodes. Lines with arrowheads are used to represent causal directions so that an arrowhead from node A to node B means variable A causes variable B. A connecting line with no arrowhead indicates the two variables are connected by information flow, but we cannot say which one causes the other.

adjacent edges when partial correlations are not statistically significant and determines causal flow directions for the remaining edges based on the partial correlations of the residuals (Spirtes et al., 2000).

TETRAD IV software (Spirtes et al., 1999) was used to generate the causal patterns among the price series. Figure 1 presents the causal structures of the price series on innovations from the variables generated by the software at the 5% significance level. The results show innovations in oil and ethanol prices are linked by a connecting edge, but not by directed paths; there are no arrows to indicate direction of causality.[4]

These results show no links between the energy and agricultural sectors, rejecting the hypothesis that instability in the energy sector causes instability in the agricultural sector. The commodity prices are all linked and there are directed graphs from both corn and soybean prices to wheat prices, indicating both corn and soybeans markets impact the wheat market. Also, innovations in corn and soybeans price series affect residuals in each other, but they are not connected by directed paths. These results are consistent with Power and Vedenov's (2009) results.

Furthermore, we use pairwise Granger causality tests (with two lags) to investigate Granger causal directions among the variables. The results are summarized in Table 5. F-test results indicated that the hypotheses that oil prices do not Granger cause ethanol and commodity prices are rejected. As expected, the direction of Granger causality runs especially strong from oil prices to ethanol prices. This relationship is unidirectional and there are no causality relationship going from ethanol or commodities price series to oil.

Also, as expected, F-test results indicate that there is a close bidirectional relationship between corn and ethanol prices. There are

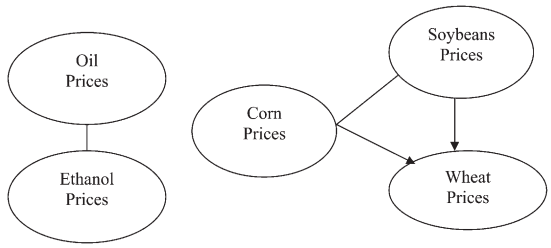

Figure 1. Causal Structures on Innovations from the Price Series

unidirectional relationships from soybeans and wheat price series to ethanol, and ethanol does not Granger cause soybeans or wheat price series. Overall, oil and all three commodity price series Granger cause ethanol prices. These results also indicate close relationships among the commodities; both corn and wheat prices Granger cause soybean prices, and there is a bidirectional relationship between corn and wheat price series.

Hence, unlike the directed graph results that showed no structural causation between the energy and agricultural sectors, these results show oil prices Granger cause all three commodity prices. It is difficult, however, to conclude that the two sets of results are completely contradictory. It is important to note that Granger causality, a concept based on prediction, does not mean real causality. The fact that a variable Granger causes another variable only means past values of that variable have some information that could help predict future values of this variable.

As seen earlier, there are strong correlations among the model variables, which could translate into the Granger causality relationship results found. It is interesting to note that crude oil prices are denominated in U.S. dollars, and as a result, oil price changes are a close substitute for exchange rates changes. Also, because commodities are traded heavily in the international markets, exchange rate changes are strongly correlated with commodity price changes.

Conclusions

A review of agricultural economics literature indicates the importance of macroeconomics, including energy impacts, in the determination

[4] According to the TETRAD software, this is a case in which an edge between A and B indicates that either A is a cause of B or B is a cause of A, or there is a common latent cause of A and B, or some combination of these, but the direction of causality is not known given the nature of residuals at hand.

Table 5. The Results of Pairwise Granger Causality Tests

Null Hypothesis	F-Statistic
Oil price does not Granger cause ethanol price	15.59***
Ethanol price does not Granger cause oil price	0.59
Corn price does not Granger cause oil price	1.63
Oil price does not Granger cause corn price	3.05**
Soybean price does not Granger cause oil price	1.70
Oil price does not Granger cause soybean price	2.39*
Wheat price does not Granger cause oil price	0.33
Oil price does not Granger cause wheat price	3.84**
Corn price does not Granger cause ethanol price	4.44***
Ethanol price does not Granger cause corn price	2.50*
Soybean price does not Granger cause ethanol price	3.35**
Ethanol price does not Granger cause soybean price	0.74
Wheat price does not Granger cause ethanol price	2.31*
Ethanol price does not Granger cause wheat price	2.23
Soybean price does not Granger cause corn price	1.87
Corn price does not Granger cause soybean price	2.79*
Wheat price does not Granger cause corn price	14.68***
Corn price does not Granger cause wheat price	3.87**
Wheat price does not Granger cause soybean price	9.76***
Soybean price does not Granger cause wheat price	0.72

*** One percent significance level; ** 5% significance level; * 10% significance level.

of agricultural commodity prices. Macroeconomic linkages to agriculture are fascinating and important determinants of farm prices and income, especially in the current context of the oil market volatility and the global economic and financial crisis. These factors are of paramount importance to farmers and affect farm income and the financial viability of farms tremendously. This is in contrast to an historical view of agricultural economics, in which farm prices and income are determined by microeconomic supply and demand factors with little regard to macroeconomic factors. Macroeconomic changes have real short-run and long-run effects on the prices of agricultural commodities. The short- and long-run impacts of macro policy could add to price and income instability.

The results of this study show that there is a strong correlation among oil and commodity prices, but the evidence for a causal link from oil to commodity prices is mixed. The directed graphs of the residuals of a VEC system incorporating five variables: oil, ethanol, corn, soybeans, and wheat prices, show there are no causal links between the energy and agricultural sectors, basically rejecting the hypothesis that instability in the energy sector causes instability in the agricultural sector. However, the results of Granger causality tests indicate crude oil prices Granger cause corn, soybeans, and wheat prices.

The results by individual commodity highlight the interlinkages of the energy and agricultural sectors. Correlations among energy, agriculture, and exchange rate markets are substantial, but when it comes to causation, the story is different. A good reason for these correlations could be the fact that grains are directly linked with ethanol and oil markets through the oil–ethanol–corn linkages. Also, a large percentage of grain output is exported and because crude oil prices are denominated in U.S. dollars, oil price hikes increase the supply of the dollar worldwide that lead to dollar depreciation and, in turn, increase demand for U.S. grain exports. Abbott, Hurt, and Tyner (2008) argue that the depreciation of the U.S. dollar is one key factor contributing to the recent food price increases.

Macro policy factors and current global market conditions are contributing to the growing biofuel industries. To diminish dependence

on foreign oil, alternative sources of energy such as ethanol could be used. This in turn would impact production and marketing of agricultural products. The energy markets and economics of ethanol production have dramatically affected both national and international grain markets. Farmers are able to at least partially reduce some risks by using techniques such as futures market, hedging, purchasing crop insurance, and diversifying crops.

Advances in technology have resulted in substantial improvements in the food supply chain, from farming to processing to retailing. New technologies like genetically modified seeds and energy efficient precision farming with GPS autoguidance, yield mapping, and improved irrigation systems have tremendously increased farm productivity. Improvements in agriculture productivity, transportation, and processing of corn to ethanol have created great new opportunities for farmers. However, using ethanol as a close substitute for gasoline has ramifications that reach far beyond the agriculture sector.

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