Inside the Black Box: Price Linkage and Transmission Between Energy and Agricultural Markets

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Introduction

The production of biofuels, particularly ethanol, has grown significantly in the last decade, driven by rising crude oil prices, policies aimed at energy independence, and environmental concerns. The increased use of corn as an ethanol feedstock has exposed agricultural markets to both input-related supply shocks stemming from rising energy prices and demand-side shifts based on biofuels' role as a petroleum substitute. Higher energy prices induce higher fertilizer and other agricultural production costs. Meanwhile, high crude oil prices make ethanol production more profitable and increase demand for corn. Given the relatively fixed number of acres for crop production, shocks to the corn market are likely to spill over into other crops and ultimately raise food prices.

Objective

This study addresses the complex relationship between energy and agricultural markets—represented by corn, ethanol, and gasoline prices—particularly in light of the growth in biofuel production. Contemporaneous price response and transmission of market shocks are investigated in a simultaneous-equation system to disclose fundamental driving forces before and after the development of large-scale ethanol production. The goal is to demonstrate a strengthening relationship among corn, ethanol, and gasoline prices.

Modeling and Empirical Strategy

First, a dynamic conditional correlation (DCC) multivariate GARCH model, proposed in Engle (2002), is employed to estimate the time varying correlations between price series. The DCC model is specified as:

(1) $r_t = H_t^{1/2} z_t;\ r_t \mid \Psi_{t-1} \sim N(0, H_t)$ and $r_t = (r_{1t}, r_{2t}, \ldots, r_{nt})'$,

where $r_{it} \equiv \log(p_{i,t} / p_{i,t-1})$ denotes the log-return of market i observed at time t, $z_t = (z_{it}, z_{2t}, \ldots, z_{nt})' \sim N(0, I_n)$, and I_n is the identity matrix of order n. The information set of time $t-1$ is represented by Ψ_{t-1}. The covariance matrix is decomposed as:

(2) $H_t = D_t R_t D_t$ where $D_t = diag\left\{\sqrt{h_{it}}\right\}$.

D_t is a diagonal matrix of time varying standard variation from univariate GARCH process, and the conditional correlation matrix is R_t. The DCC model is estimated following the two-step approach described in Engle (2002). In this study, bivariate DCC models are estimated to establish dynamic pairwise correlations between corn, ethanol, and gasoline prices.

Second, a structural vector autoregression (SVAR) model is employed to jointly explain the contemporaneous evolution of energy and agricultural prices. The SVAR model is represented as

(3) $Ay_{i,t} = \alpha + \sum_{j=1}^{J} C_j y_{i,t-j} + \varphi_i z_t + \varepsilon_{i,t}$

where $\mathbf{y}_{i,t} = (P_{c,t}, P_{e,t}, P_{g,t})$. The symbols $P_{c,t}$, $P_{e,t}$, and $P_{g,t}$ denote corn, ethanol and gasoline prices respectively. Off-diagonal elements of Matrix $\mathbf{A}$ capture the contemporaneous interactions across prices, and $\mathbf{C}$ captures the lagged effects of the endogenous variables $\mathbf{y}_{i,t}$. z_t is the common factor affecting all prices in the system, the crude oil price in our case. The structural residual $\varepsilon_{i,t}$ relates to reduced-form residuals through matrix $\mathbf{A}$. The idea of "identification through heteroskedasticity (IDH)," introduced by Rigobon (2003), is applied for estimation and inference. The IDH method solves the identification problem by utilizing the existence of heteroskedastic regimes associated with the recent boom in energy and agricultural prices.

Data: Prices are the daily settlement prices of the nearest-to-maturity contracts traded in the corresponding futures markets, which are the Chicago Board of Trade (CBOT) for corn and ethanol contracts, and the New York Mercantile Exchange (NYMEX) for gasoline. The sample period is from March 20, 2005, to March 20, 2011.

Results and Discussion: Expansion of ethanol production has significantly strengthened the correlation between corn and ethanol markets (fig. 1). The correlations of corn/gasoline and ethanol/gasoline prices show similar patterns over the sample period, gradually increasing until 2009 and then declining. Using the test described in Bai and Perron (2003), a structural change point is identified at March 25, 2008, producing one subsample before and one after the estimated change point.

The SVAR model is estimated on each of the subsamples. In period I without large-scale ethanol production, the gasoline and corn markets are generally independent. In period II when ethanol production expands substantially, the two markets become integrated, as verified by the statistically significant contemporaneous price impacts on each other (table 1).

We further illustrate the strengthened market relationship by variance decomposition, which demonstrates how much of the unanticipated changes in price are explained by shocks in other markets. In period II for each of the three markets, a significant and relatively large share of the price behavior is explained by the other two markets (table 2). Variation in gasoline prices can be explained by shocks to ethanol markets (accounting for 15 percent of the variation in gas prices) and corn markets (16 percent). At the same time, 28 percent of the variation of ethanol prices can be attributed to corn price changes, while shocks to ethanol prices account for 22 percent of the variation in corn prices.

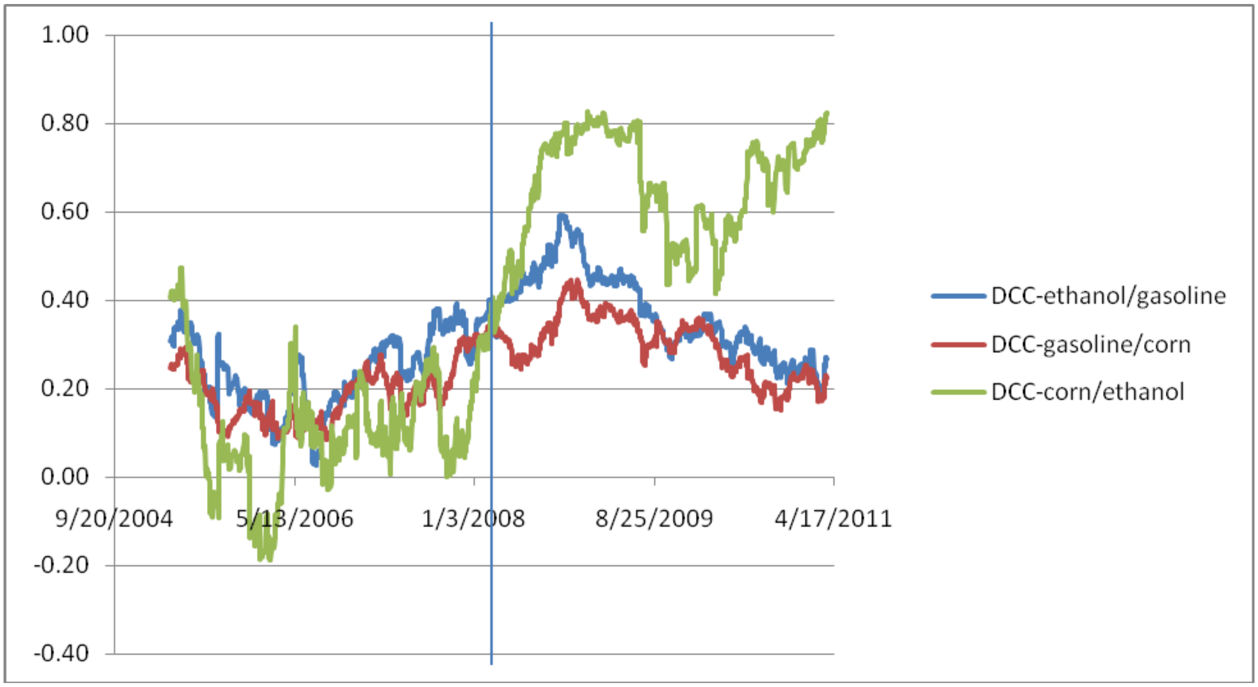
References

Bai, J., and P. Perron. 2003. "Computation and Analysis of Multiple Structural Change Models," *Journal of Applied Econometrics* 18: 1-22.

Engle, R. 2002. "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models," *Journal of Business and Economic Statistics* 20: 339-350.

Rigobon, R. 2003. "Identification through Heteroskedasticity," *Review of Economics and Statistics* 85: 777-792.

Figure 1. Estimated dynamic conditional correlations for ethanol/gasoline/corn prices



Note: Prices are the daily settlement prices of the nearest-to-maturity contracts traded in the corresponding futures markets, which are the Chicago Board of Trade (CBOT) for corn and ethanol contracts, and the New York Mercantile Exchange (NYMEX) for gasoline.

Table 1. Estimation results for the SVAR model

Period I	Ethanol	Gasoline	Corn
Ethanol	1.00	0.04	-0.03
Gasoline	0.09	1.00	-0.04
Corn	-0.001	-0.004	1.00
Period II			
Ethanol	1.00	0.08**	0.45***
Gasoline	0.40***	1.00	0.28***
Corn	0.66***	0.07***	1.00

Note: Single (*), double (**), and triple (***) asterisks denote significance at 0.10, 0.05, and 0.01 levels, respectively.

Table 2. Estimation results for variance decomposition (in percentage)

Period I	Ethanol	Gasoline	Corn
e_Ethanol	99.11***	1.37	0.11
e_Gasoline	0.38	97.49***	0.08
e_Corn	0.51	1.14	99.81***
Period II			
e_Ethanol	69.59***	14.81***	22.44***
e_Gasoline	2.82	69.51***	2.43
e_Corn	27.59***	15.68***	75.13***

Notes: The table reports the share of the variance of each market in percentage (ethanol, gasoline and corn) that is explained by the various structural shocks (e_ethanol, e_gasoline, and e_corn). Single (*), double (**), and triple (***) asterisks denote significance at 0.10, 0.05, and 0.01 levels, respectively.