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Disentangling Corn Price Volatility: The Role of Global Demand, Speculation, and Energy

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Despite extensive literature on contributing factors to the high commodity prices and volatility in the recent years, few have examined these causal factors together in one analysis. We quantify empirically the relative importance of three factors: global demand, speculation, and energy prices/policy in explaining corn price volatility. A structural vector auto-regression model is developed and variance decomposition is applied to measure the contribution of each factor in explaining corn price variation. We find that speculation is important, but only in the short run. However, in the long run, energy is the most important followed by global demand.

Key Words: corn, global demand, energy, price volatility, speculation, structural vector autoregression

JEL Classifications: Q11, C32, G2, Q4

Agricultural commodity prices have exhibited extreme price volatility since mid-2007 (Schnepf, 2008). Prices for crops such as corn, wheat, rice, and soybeans rose to record or near-record levels in early 2008, and then fell sharply in the second half of 2008. Once again, prices rose sharply in mid-2010 and peaked in early 2011. For example, number two yellow corn prices (U.S. Central Illinois) increased to $6.55 per bushel in June 2008 and then dropped to $3.10 per bushel in September 2009. As of August 2011, number two yellow corn prices were as high as $7.30 per bushel (U.S. Department of Agriculture Economic Research Service, 2011).

Commodity investment behavior, farm income and policy, and food security are all impacted by agricultural price volatility. Particularly, extreme volatile prices have increased the risk associated with grain merchandising and dramatically increased the cost of hedging at commodity futures exchanges. While high commodity prices have raised farm income and lowered government farm program costs, they have also caused food price inflation by raising feed and input costs for livestock producers and food processors. In developed countries, agricultural commodity prices have limited impact on food prices due to the fact that the actual agricultural input cost is small relative to the other input costs. However, high and volatile food prices can be quite problematic for import-dependent, less developed nations. For instance, it is noted that volatility in world soybean prices during the 2007–2009 period resulted in increased poverty in Indonesia (Dartanto and Usman, 2011).

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Despite the extensive literature on factors contributing to the high and volatile commodity/food prices, the relative importance of individual factors to the price boom and bust continues to be a contentious issue. Commonly cited causes for the recent rise in commodity prices include: 1) demand growth in emerging economies such as Brazil, China, and India due to higher per capita income; 2) energy prices driving up the cost of food production and distribution; 3) biofuels policy in the United States, Brazil, and the European Union (EU), shifting crop use from food to fuel; 4) speculation and the rising involvement of hedge and index funds in commodity futures trading; 5) supply shortfalls due to poor weather; 6) declining value of the U.S. dollar and relatively low interest rates; and 7) hoarding and export controls. Although each of these factors may have played some role in rising commodity prices, demand growth in emerging economies, energy prices and biofuels policy, and speculation are perhaps the most contentious (Baffes and Haniotis, 2010).

While many studies have examined these factors in isolation (e.g., the causal relationship between speculation and agricultural commodity prices), it is important to account for contributing factors all together to access any ceteris paribus effects. Thus, our goal is to quantify empirically the relative importance of each key factor (demand growth, energy prices and policy, and speculation) in explaining the volatility in commodity prices. Although there is a strong price correlation among agricultural commodities, price fluctuations often vary from crop to crop indicating that a sector specific analysis is appropriate. In this study, we focus on the corn sector, which is particularly important to U.S. agriculture, where we measure the relative importance of global demand growth, speculation, and energy prices and policy in explaining corn price volatility.

A structural vector autoregression (SVAR) model is developed and variance decomposition is applied to measure the relative importance of each key factor in explaining corn price variation. We use the Baltic Dry Index (BDI) to proxy global corn demand, Working's speculative index to proxy speculation in the corn futures market, and crude oil prices and U.S. ethanol production to capture the effect of energy prices and policy. We find that among these three key factors, speculation is important in explaining corn price variation only in the short run. However, in the long run, energy prices are the most important followed by global demand. In the long run, the effect of speculation is minimal given the effects of global demand and energy.

In the following section we provide a literature review highlighting the consensus (or lack thereof) among researchers on the importance of demand growth, energy, or speculation in causing commodity price volatility. We describe the econometric procedure in the third section. Next we describe the data used for analysis. In the fifth section, we report and discuss the empirical results. The last section concludes the paper.

Background

Of the factors considered in this study, the literature on the effects of oil/energy prices and speculation on commodity prices is extensive, while the literature on the effects of demand growth in emerging economies is much less so. The primary motivation for studying the relationship between energy and commodity prices has changed in recent years. Prior to the recent emergence of large scale biofuels production, agricultural and energy prices have traditionally exhibited relatively low correlation (Hertel and Beckman, 2011). Although in years prior, the primary causal relationship was due to energy being an input in production, the increased use of agricultural commodities in energy production has created an even greater linkage between the two markets due to demand-side phenomena (Du and McPhail, 2012; Tyner and Taheripour, 2008). A number of studies have found clear evidence that the relationship between crude oil and corn prices significantly increased over time resulting from the growing use of corn for ethanol production (Harri, Nalley, and Hudson, 2009; Natanelov et al., 2011). While most studies support a stronger link between agriculture and energy, the extent to which biofuels are contributing to high commodity/food prices is still under debate. Some found little evidence that the demand for grains and oilseeds as biofuel feedstocks was a cause of the recent spike in prices (Gilbert, 2010), while others argue that biofuel production in the United States and the EU was the most important factor (Mitchell, 2008).

The debate on the effect of speculation and investor behavior on commodity prices was fueled by the dramatic increase in commodity futures prices and volatility from 2005–2008, which followed a period during which index traders took on substantial futures positions. Although legislators have considered ways to curb excessive speculation and the Commodity Futures Trading Commission (CFTC) moved to more strict enforcement of speculative position limits, a number of studies found no empirical evidence to support the claim that long-only index funds impact commodity futures prices (Irwin and Sanders, 2011; Irwin, Sanders, and Merrin, 2009; Power and Turvey, 2011). Although the "anti-speculation" side largely included certain hedge fund managers, politicians, and commodity users, economists are far from reaching a consensus. For example, prior to the two most recent price booms, scholars found that an unexpected increase in commodity futures trading caused an increase in cash price volatility (Yang, Balyeat, and Leatham, 2005).

The assertion that demand growth in emerging markets contributed to the recent commodity price booms is rooted in the notion that global supply constraints limit production responses from keeping pace with global demand and result in higher agricultural prices. While the responsiveness of agricultural prices to the balance between consumption, supply, and stocks is not new, the recent economic growth and resulting demand growth experienced in emerging economies such as Brazil, China, and India has brought this issue to the forefront. The effects of demand growth on price volatility are more subtle. Rising per capita income could result in more inelastic demand leading to greater price sensitivity to agricultural supply shocks (Alber, 2010). However, some argue that income and demand growth in China cannot be blamed for the recent global food price spike (Carter, Zhong, and Zhu, 2009).

Model

We quantify empirically the relative importance of three key factors, global demand, speculation, and energy, in explaining the volatility in corn prices. The dynamic nature of agricultural commodity prices makes this analysis ideally suited for an SVAR, which has been an important tool in analyzing monetary, fiscal, and technology shocks (Enders, 2010). Vector autoregression (VAR) is a reduced-form method, so it is difficult to interpret the results unless the reduced form is linked to an economic model. SVAR imposes economic structure on the contemporaneous movements of the variables. By doing so, it allows for the identification of model parameters, and also provides a unique decomposition of prices into economically meaningful shocks. Additionally, variance decomposition allows us to evaluate the overall importance of each shock in explaining the variance of prices of interest.

We propose a five-variable SVAR model that jointly explains the evolution of the Baltic Dry Index BDI_t, crude oil prices Po_t, U.S. ethanol production Se_t, Working's speculative index SP_t (Working, 1960), and U.S. corn prices Pc_t. Due to the data limitations of actual corn demand, we use the BDI as a proxy for the global demand of corn, which is a widely accepted indicator of global economic growth and is a key factor affecting the growth in global corn demand (Trostle, 2008). The BDI is a maritime shipping index published by the Baltic Exchange in London, which measures charter rates for shipping dry bulk commodities such as grain, coal, and other raw materials (EODData, 2011). The BDI can be viewed as the equilibrium price of shipping raw material across various ocean routes. Because the supply curve of shipping is relatively inelastic in the short and intermediate run, changes in BDI are largely determined by changes in the global demand for dry bulk commodities (Kilian, 2009).

The crude oil price and U.S. ethanol production are used to capture the effect of energy prices and policy on corn prices. High crude oil prices increase the demand for ethanol as a substitute and make ethanol production relatively more profitable, and thus increase the demand for corn. On the other hand, high crude oil prices also induce high fertilizer prices and fuel cost and contribute to high transportation cost, and thus lead to high production cost for corn. Therefore, a crude oil price shock can lead to both a positive corn demand shock and a negative corn supply shock. The growth of the U.S. ethanol market is driven by various forms of government support, such as mandates under the Renewable Fuel Standard and the Volumetric Ethanol Excise Tax Credit. The Volumetric Ethanol Excise Tax Credit has long been in place and contributed to the build-up of the U.S. ethanol industry. The Renewable Fuel Standard originated from the Energy Policy Act of 2005 and its scope was expanded by the Energy Independence and Security Act of 2007. As a result of high crude oil prices and government support, U.S. ethanol production reached 13.23 billion gallons in 2010 and the corn used for ethanol production as a share of total corn use was about 37% for the 2010 marketing year.

The Working's speculative index is used to proxy speculation in the corn futures market. Speculation in this context is noncommercial investment in commodity futures through index funds and other financial instruments. Most noncommercial contracts do not result in the delivery or inventory of the physical commodity. Many question whether speculative buying by index funds in commodity futures has created a "bubble" in commodity prices. We use Working's speculative index to measure the intensity of speculation relative to short hedging in the corn futures market. This index is defined as the ratio of speculation positions (short or long) to total hedging positions. For traders in the futures market who hold positions in futures at or above specific reporting levels, the CFTC classifies their futures positions as either "commercial" or "noncommercial." By definition, commercial positions in a commodity are held for hedging purposes, while noncommercial positions mainly represent speculative activity to pursue financial profits. The speculative index T is constructed using CFTC trader position data as follows:

$$(1)\quad \begin{aligned} T &= 1 + SS/(HS + HL) \quad \text{if} \quad HS > HL \\ T &= 1 + SL/(HS + HL) \quad \text{if} \quad HL > HS, \end{aligned}$$

where $SS(SL)$ represents speculative or noncommercial short (long) positions, while $HS(HL)$ represents short (long) hedged/commercial positions. If speculative or hedging cover all categories of positions in the futures market, the relation between short and long positions must hold as $SS + HS = SL + HL$. When long and short hedging positions do not offset each other, speculation is necessary to absorb the residual hedging position. For example, in considering the extreme case where $HL > HS = 0$, the minimum and necessary level of speculation (SS) is HL ; in this case, SL is equal to zero and the speculation index T is equal to 1. Thus, the speculation index is used to measure the extent to which speculation exceeds the minimum level necessary to offset hedging positions.

The SVAR representation is:

$$(2)\quad \mathrm{A}_0\mathrm{x}_t = \alpha + \sum_{i=1}^{p} \mathrm{A}_i\mathrm{x}_{t-i} + \varphi_i\mathrm{z}_t + \varepsilon_t,$$

where $\mathrm{x}_t = (BDI_t, Po_t, Se_t, SP_t, Pc_t)$, off-diagonal elements of matrix A_0 capture the contemporaneous interactions across variables, p is the lag order, A_i captures the lagged effects of the endogenous variables, z_t is a vector of control variables (e.g., value of the U.S. dollar), and ε_t denotes a vector of serially and mutually uncorrelated structural innovations. The depreciation of the U.S. dollar has been emphasized as an important factor contributing to the commodity price boom (Abbott, Hurt, and Tyner, 2008), thus our control variable is the value of the dollar. We propose that real corn prices are driven by shocks in 1) global demand; 2) crude oil prices; 3) ethanol demand; 4) speculation demand; and 5) the corn market. Corn market shocks include any other shocks affecting corn prices but not captured by global demand shocks, crude oil price shocks, ethanol demand shocks, or speculation demand shocks (e.g., yield shocks caused by abnormal weather, trade policy shocks such as export quotas and bans, or macroeconomic shocks such as changes in the value of the U.S. dollar or interest rates). We are interested in the importance of each shock in explaining the fluctuations in real corn prices. These questions can be addressed by computing the forecast error variance decomposition based on the estimated SVAR model.

The reduced-form VAR representation based on the SVAR model is

$$\text{(3)} \qquad \mathrm{x}_t = \mathrm{A}_0^{-1}\alpha + \sum_{i=1}^{p} \mathrm{A}_0^{-1}\mathrm{A}_i\mathrm{x}_{t-i} + \mathrm{A}_0^{-1}\varphi_i\mathrm{z}_t + \mathrm{e}_t.$$

If A_0^{-1} is known, we can calculate the dynamic structure represented by SVAR from the reduced-form VAR coefficients, and also derive the structural shocks ε_t from estimated residuals $\varepsilon_t = \mathrm{A}_0\mathrm{e}_t$. However, the coefficients in A_0^{-1} are unknown, and to achieve the identification of the structural parameters, we impose theoretical restrictions to reduce the number of unknown structural parameters to be less than or equal to the number of estimated parameters in the VAR residual variance-covariance matrix. Based on economic intuition, the following restrictions are imposed to identify structural parameters:

$$\text{(4)} \qquad \mathrm{e}_t = \begin{pmatrix} e_t^{BDI} \\ e_t^{Po} \\ e_t^{Se} \\ e_t^{SP} \\ e_t^{Pc} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^{global\_demand\_shock} \\ \varepsilon_t^{oil\_price\_shock} \\ \varepsilon_t^{ethanol\_demand\_shock} \\ \varepsilon_t^{speculation\_demand\_shock} \\ \varepsilon_t^{corn\_market\_shock} \end{pmatrix}.$$

We achieve the recursive structure of the SVAR model by assuming that not all variables of interest will respond to shocks contemporaneously. Equation (4) presents all these assumptions. We assume that the global demand for corn does not respond to a crude oil price shock, ethanol demand shock, speculation shock, or a corn market shock within a month. We also assume that the crude oil price does not respond to an ethanol demand shock, speculation demand shock, or corn market shock within a month. Additionally, U.S. ethanol production is assumed to be not responding to a shock in speculation demand or corn market within a month, while speculation in the corn futures market is assumed to be not responding to a corn market shock within a month. However, we assume that real corn prices respond to all shocks within a month.

Data

Figure 1 shows the monthly data (January 2000 to July 2011) for the key variables in the model. For the BDI, we use the average daily close price for each month from the Baltic Exchange. We obtain imported crude oil prices and U.S. ethanol production from the Energy Information Administration. The number of hedging and speculation positions in corn futures at Chicago Board of Trade is obtained from the Historical Commitments of Traders reports published by the U.S. CFTC (2012). Corn prices are settlement prices of the nearest to maturity contracts traded at the Chicago Mercantile Exchange. The value of the dollar is proxied by the Trade Weight Index of Major Currencies, a daily index published by the Federal Reserve Bank of St. Louis (2011). It is a weighted average of the U.S. dollar to a set of major foreign currencies including the euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. Nominal prices and indices are deflated by U.S. Consumer Price Index (CPI). Specifically, the real values of BDI, crude oil prices, and corn prices are calculated by dividing nominal indices/prices in a given month by the ratio of the CPI in that month to the CPI in July 2011. We use the level change in monthly U.S. ethanol production to capture the change in corn demand for ethanol production (McPhail, 2011).

Empirical Strategy and Results

We first determine whether a stable long-run relationship exists among the monthly time series. Johansen's test for cointegration is applied. The maximum eigenvalue statistics (of rank 0) are smaller than the critical value at the 5% significance level. This implies that

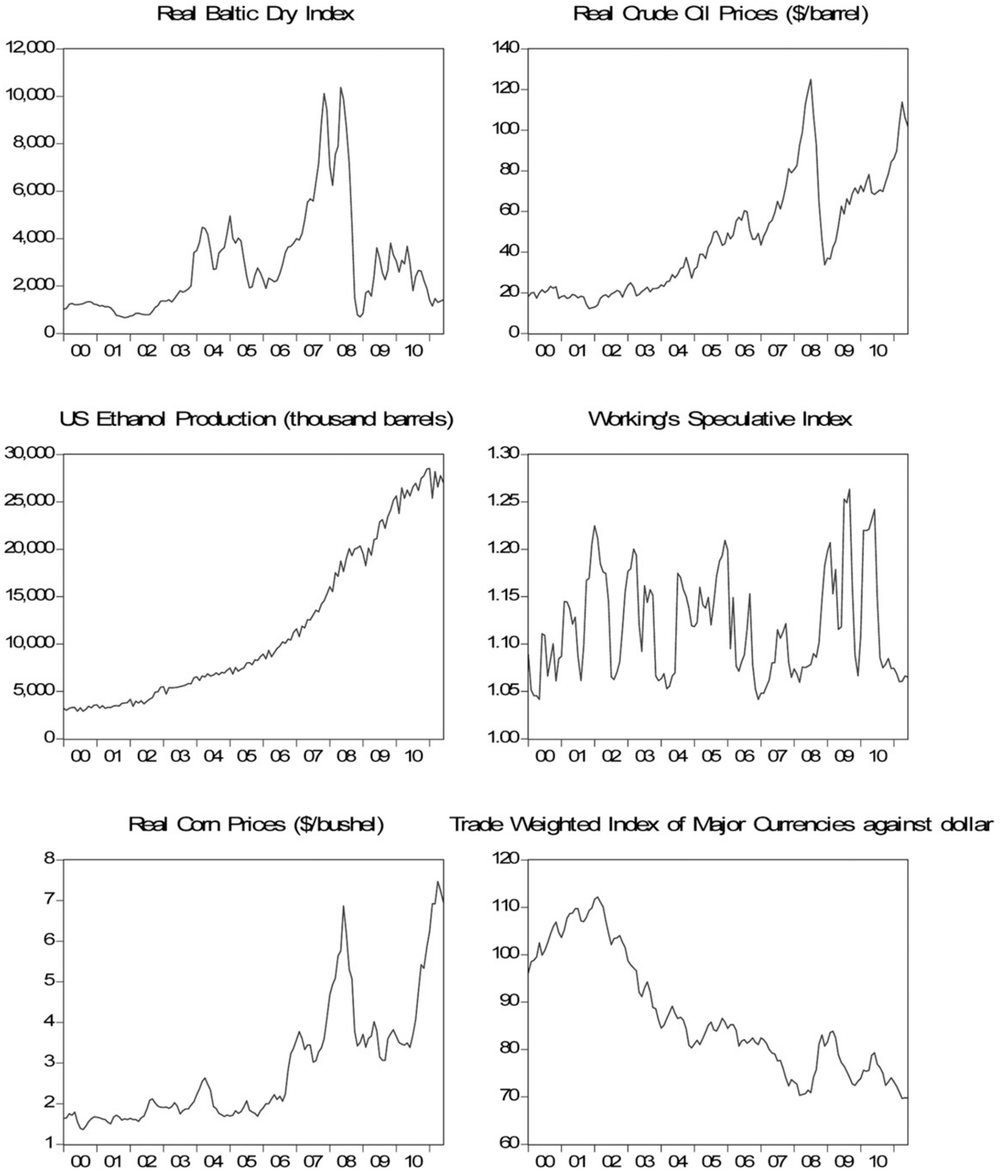


Figure 1. Data Plots for Key Variables (January 2000 to July 2011)

we fail to reject the null hypothesis of no cointegration. The lack of cointegration negates the need for using a vector error correction model and suggests that we should examine the short-run dynamics using an unrestricted VAR model.

For our VAR analysis, first we test whether the monthly time series of key variables are stationary. Based on results, we reject the null, that is, the existence of unit root for these monthly series at the 10% significance level. We then utilize a sequential modified log likelihood ratio test and the Akaike information criterion to choose the number of lags to include in a SVAR model. A two-month lag specification is selected.

Impulse Response Analysis

To examine the distinct response of real corn prices to shocks in global demand, crude oil prices, ethanol demand, and speculation demand, we use impulse response analysis. Figure 2 presents the dynamic responses of real corn prices to each shock from impact to month 10. Solid line represents the mean impact. Dotted lines represent two standard deviation impacts from the mean. Standard errors for the impulse responses are calculated using the Monte Carlo approach (Runkle, 2002). As expected, a rise in global corn demand increases real corn prices. This positive response is statistically significant, peaks after four months, and then dies out gradually.

A rise in crude oil prices also increases real corn prices, but unlike global corn demand, this positive response is more persistent. As we discussed earlier, the reason is the following: high crude oil prices lead to high transportation costs, fertilizer prices, etc., and thus increase the production cost of corn. Also, high crude oil prices increase the demand for ethanol, and thus increase the demand for corn. However, the response of real corn prices to an increase in corn as an ethanol feedstock (ethanol demand shock), which is likely due to government policy and support, is not statistically significant throughout the impulse response period. The insignificance of ethanol demand might be due to the responsiveness of corn prices to ethanol demand being captured by the response to crude oil prices.

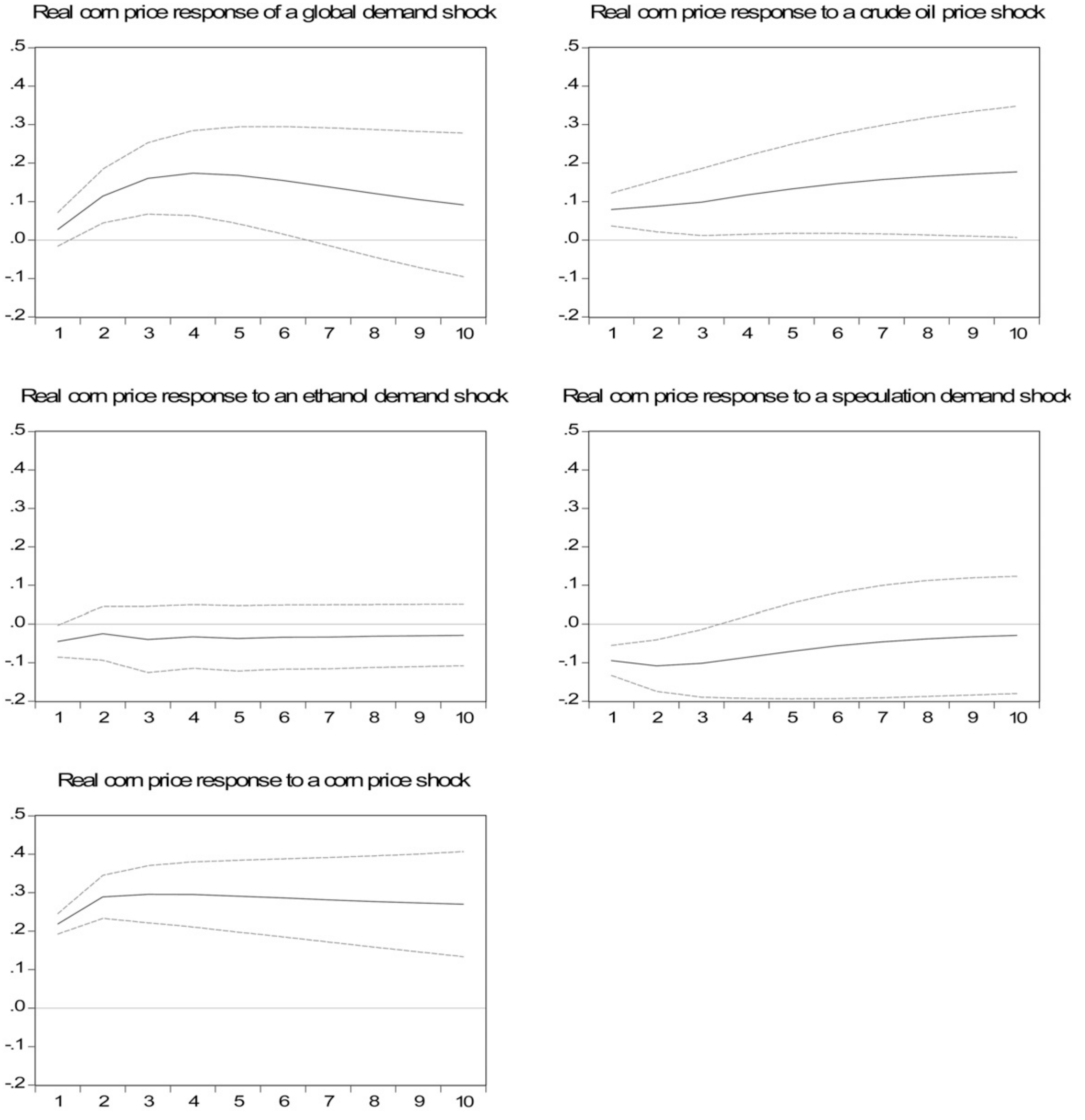
Interestingly, the response of real corn prices to an increase in speculation is initially negative and statistically significant from month one to three, but gradually dies out thereafter. This suggests that the effect of speculation on corn prices is short-lived, which is consistent with the argument that speculative buying by index funds in corn futures did not create a persistent "bubble" in corn prices. A bubble means that actual prices stray from their fundamental values determined by demand and supply. This is consistent with the findings in past research (Irwin and Sanders, 2011; Irwin, Sanders, and Merrin, 2009; Sanders and Irwin, 2010). Bubble arguments reflect misunderstandings of how commodity futures markets actually work, and a number of facts about the situation in commodity markets are inconsistent with the existence of a substantial bubble in commodity prices (Irwin, Sanders, and Merrin, 2009).

Other results are intuitive and consistent with the literature. For example, we show that global corn demand as measured by BDI responds negatively to a positive ethanol demand shock with statistical significance from month one to two. This is to be expected because as more corn is used for ethanol production, less is exported to meet global demand. We also show that real crude oil prices respond positively to a positive global demand shock with statistical significance from month one to eight, which is consistent with findings from Kilian (2009). Real crude oil prices are also found to respond negatively to a positive ethanol demand shock with statistical significance from month one to three, which is consistent with findings from McPhail (2011).

Variance Decomposition

We are interested in the importance of each shock in explaining the fluctuations in real corn prices. This is addressed by computing the forecast error variance decomposition based on the SVAR estimates. Variance decomposition allocates each variable's forecast error variance to the individual shocks, which is a measure of the quantitative effect that the shocks have on the variables.

Table 1 reports the percentage of the variance of the error made in forecasting real corn prices due to a specific shock at a specific time horizon. These estimates show the relative importance of each shock in explaining the fluctuations in real corn prices. Note that these estimates are based on historical averages for the period since 2000, but the relative importance might be quite different from one historical episode to the next. Results show that within a month about 73% of variation in real



Note: Solid line represents the mean impact. Dotted lines represent two standard deviation impacts from the mean. Standard errors for the impulse responses are calculated using the Monte Carlo approach of (Runkle, 2002).

Figure 2. Real Corn Price ($ per bushel) Responses to Each Shock

corn prices is accounted for by corn market shocks, which include any shocks affecting corn prices not captured by shocks in global demand, crude oil prices, ethanol demand, or speculation demand. Additionally, speculation demand shocks explain about 14% of corn price variation within a month, crude oil prices explain about 9.5%, and ethanol demand explains about 3%, while global demand explains about 1%. Note that within the first month speculation demand is the most important, while global demand is the least important. In the short run, commodity prices typically are discovered in futures markets and price changes are passed from futures to cash markets. When speculation or the flow of index funds in commodity markets increases, traders might interpret this to reflect valuable private

Table 1. Percent Contribution of Each Shock to the Variability in Real Corn Prices

Months	Global Demand Shocks	Crude Oil Price Shocks	Ethanol Demand Shocks	Corn Speculation Demand Shocks	Corn Market Shocks
1	1.18	9.48	3.02	13.56	72.76
6	16.81	10.54	1.08	6.43	65.14
12	13.05	17.97	0.92	3.74	64.33
24	7.44	26.42	0.76	2.08	63.31
36	5.14	30.27	0.69	1.43	62.47
48	3.95	32.34	0.66	1.09	61.97
60	3.22	33.60	0.64	0.88	61.66

information about future commodity prices. Therefore, prices change as traders adjust their demand based on this information. However, it is unlikely that this could happen on a wide enough scale to consistently drive price movements. Long term equilibrium prices are ultimately determined by the buying and selling of physical commodities in the cash market and not futures market speculation.

At six months, global demand shocks become the most important (other than corn market shocks), explaining about 17% of corn price variation, while shocks in speculation demand become much less important, explaining about 6%. However, from 12 months and beyond, crude oil price shocks surpass global demand shocks and become the most important in explaining corn price variation. As we discussed earlier, long run equilibrium prices are determined by the demand and supply of physical commodities. High crude oil prices affect both corn demand and supply in the cash market, and contributed to the build-up of the ethanol industry, which uses corn as its main feedstock. As discussed earlier, global economic growth increases the demand for corn. Particularly, rising per capita income could result in more inelastic demand leading to greater price sensitivity to supply shocks. Although the global demand effect is significantly smaller than crude oil, we see that it is also important in explaining corn price volatility in the long run.

Conclusions

We measure the relative importance of global demand, speculation, and energy in explaining corn price volatility. We use the Baltic Dry Index to proxy global corn demand, Working's speculative index to proxy the speculation in corn futures, and crude oil prices and U.S. ethanol production to capture the effects of energy prices and policy on corn prices. In addition to corn market shocks, speculation is the most important of the considered factors in explaining corn price variations, but only in the short run. However, in the long run, energy is the most important followed by global demand, while the effect of speculation is minimal given the effects of global demand and energy.

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