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How Strong are the Linkages among Agricultural, Oil, and Exchange Rate Markets?

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Highly fluctuating agricultural prices have rekindled questions regarding the influence of volatile oil and exchange rates markets on dynamic behavior. Using weekly cash data from 1998 to 2009 and VAR and VECM procedures, we estimate the linkages among several agricultural grain and livestock commodities, oil, and exchange rates. We identify a structural break in mid 2006, and perform the analysis for each period. In the first period, agricultural commodity prices are most influenced by idiosyncratic factors as reflected in own lagged prices, and exchange rates and crude oil have limited effect on agricultural markets. In the second period the effect of own lags in the agricultural markets are smaller and the effect of the exchange rate and crude oil are more pronounced, especially in the corn market. In recent years, agricultural commodity markets appear more dependent on exchange rates and to a lesser extent on oil prices.

Keywords: commodity prices, exchange rate, impulse response, market linkages, structural break

Introduction

Linkages between the agricultural markets and macroeconomic factors have long been studied. Seminal work by Schuh (1974) suggesting that the exchange rate plays an important role in transmitting macroeconomic factors to agricultural prices has motivated considerable empirical research (e.g., Bessler and Babula 1987, Bradshaw and Orden 1990, Harri, Nalley, and Hudson 2009). Exchange rates are often viewed as good indicators of commodity prices because they capture market expectations of future price dynamics, the effect on future exports, and in future exchange rate values (Chen, Rogoff, and Rossi 2009). However, despite efforts to estimate these relationships for a variety of the agricultural markets, the extent to which exchange rates influence and could be used to forecast agricultural commodity prices is still unclear.

Using a vector autoregressive model (VAR), Bessler and Babula (1987) find limited evidence that exchange rates can improve price forecasting in wheat markets. Bradshaw and Orden (1990) extend the analysis by adding corn and soybeans and estimating alternative time series models including ARIMA and a restricted VAR. Their findings suggest that (Granger) causality of exchange rate to commodity prices is sensitive to the model specification used. Further, the restricted VAR appears to have better out-of-sample forecast ability relative to other models, including an unrestricted VAR specification. In light of the increasing importance of energy markets in the economy and agriculture, researchers have begun to develop more comprehensive models to understand market and macroeconomic linkages. For instance, Park and Fortenberry (2007) analyze the corn market, and among other things, conclude a more thorough study including other commodity markets as well as modeling procedure is needed to capture the dynamics between ethanol and corn prices. Using a multivariate time series framework, Tejeda and Goodwin (2009) investigate the effect of ethanol shocks on corn, soybean, and cattle prices, and conclude that dynamic correlations between markets change, influenced by increases in ethanol production. However they recognize that further research including other variables such

as the exchange rate is needed to better understand the relationships among different markets. More recently, Harri, Nalley, and Hudson (2009) using a VAR model find evidence of a relationship between exchange rate, corn, and oil. Further, Yeboah, Shaik, and Allen (2009) find significant relationships between the exchange rate and agricultural inputs, but do not examine the linkages between the exchange rate and agricultural output prices.

These studies suggest modeling interdependencies between the different markets is complex. For instance, results of the direction of causality from exchange rates to prices are mixed and highly dependent on the specification of the model used. Also, failure to include important markets can hamper estimation of the linkages between markets, and reduce the likelihood of developing predictive relationships. Here we propose research to identify these interdependencies in a more systematic manner.

The purpose of the paper is to estimate more precisely the relationship between the exchange rate, agricultural commodity prices, and the energy complex using a VAR framework. VAR models which have been a primary procedure to investigate market linkages have been criticized because of over-parameterization which makes estimates less reliable and forecasts less precise. Also, identification problems can lead to arbitrary restrictions in the error variance matrix, making impulse response functions difficult to interpret (Enders 2000). Here we follow the sequential elimination procedure in Lütkepol (2005) to restrict the VAR model, which leads to a more reliable impulse response function and in turn permits a better assessment of the effects of shocks to the system. We investigate the corn, wheat, cattle, hogs, crude oil prices, and exchange rates to clarify these important and timely relationships. Corn and wheat are major U.S. exports, and cattle prices are linked through feed use. We use weekly averages of cash prices for the period 1998-2009. In light of recent price behavior, market linkages as well as the transmission of macroeconomic factors to agricultural markets should be of interest to producers as well as to policy makers. Improved understanding of these relationships and their magnitude could be used develop marketing strategies, and could provide policy makers with added insights into the effect of new policies to related markets.

Methods

The substantial price increases in grains and crude oil observed in recent years suggest the presence of a structural break in these markets. Such increases may violate the stationarity assumption for econometric modeling if the price levels or variance is significantly different before and after the structural break (Frank and Garcia 2009). Stationarity tests performed over a long period of time can be influenced by structural changes which introduce a trend that can bias unit root tests towards non-rejection of the null hypothesis (Tomek 1997). We therefore perform stationarity tests for each data series taking into account potential break points. We use the Zivot-Andrews (1992) test to identify the break points and assess the presence of unit roots. In the Zivot-Andrews test the break points are not selected a priori but are estimated recursively by choosing the point in time for which the absolute value of the Augmented Dickey Fuller test statistic is minimized.

We expect that crude oil prices, exchange rates, and agricultural commodity prices are interrelated, and that the relationship may have changed over time. Macroeconomic variables

may have driven commodity prices upward. Major commodity prices are denominated in US dollars, and its observed decline resulted in cheaper commodities for the rest of the world, which in turn increased the demand and prices (McCalla 2009). Harri, Nalley, and Hudson (2009) suggest crude oil prices and agricultural commodity prices are related through the exchange rate, input prices, and competition with biofuels. Exchange rates have been regarded as good indicators of commodity markets as they capture future market expectations (Chen, Rogoff, and Rossi 2009).

We estimate a VAR model to identify these market interdependencies. In the VAR model, all commodity prices are affected by current and past realizations of other commodities and the exchange rate. When prices are not stationary, the VAR model can be estimated in difference form. The VAR model in its reduced form is,

$$\Delta p_t = A_1 \Delta p_{t-1} + A_2 \Delta p_{t-2} + \ldots + A_j \Delta p_{t-j} + u_t \quad (1)$$

where: $\Delta p_t = (\Delta p_{1t}, \ldots, \Delta p_{Kt})'$ is a vector of K first differenced price series, each including T observations, K= {exchange rate, crude oil, corn, wheat, live cattle, lean hogs}, each $\Delta p_{t-j} = (\Delta p_{t-j}, \ldots, \Delta p_{Kt-j})'$ is a vector of K j-lagged prices, $j = 1 \ldots J$, each A_j is a (K x K) matrix of coefficients, $u_t = (u_{1t}, \ldots, u_{Kt})'$ is a vector of K residual series, $u_t \sim (0, \Sigma_u)$, and $\Sigma_u = E(u_t u_t')$.

Data series that fail to reject the null hypothesis of unit root are differenced and the stationarity test is performed again on the new differenced series. If the series are integrated of the same order a cointegrating relationship may exist. We test for cointegration following Johansen's procedure. When a cointegrating relationship is found, we estimate a vector error correction (VEC) model as follows,

$$\Delta p_t = \Pi p_{t-1} + \Gamma_1 \Delta p_{t-1} + \ldots + \Gamma_{j-1} \Delta p_{t-j+1} + u_t \quad (2)$$

where: $\Delta p_t = (\Delta p_{1t}, \ldots, \Delta p_{Kt})'$ is a vector of K price series, each including T observations, K= {exchange rate, crude oil, corn, wheat, live cattle, lean hogs}, $p_{t-1} = (p_{1t-1}, \ldots, p_{Kt-1})'$ is a vector of K one-lagged prices, each $\Delta p_{t-j} = (\Delta p_{t-j}, \ldots, \Delta p_{Kt-j})'$ is a vector of K j-lagged differenced prices, $j = 1 \ldots J$, Π is a (K x K) matrix of long-run coefficients, each Γ_j is a (K x K) matrix of short-run coefficients, and $u_t = (u_{1t}, \ldots, u_{Kt})'$ is a vector of K residual series.

The number of lags j to include in the model is first determined based on the multivariate AIC criteria (Lütkepohl 2004), $AIC(j) = \log\left|\widetilde{\Sigma}_u(j)\right| + (2/T) jK^2$ where $\widetilde{\Sigma}_u(j) = T^{-1}\Sigma_{t=1}^{T} \hat{u}_t \hat{u}_t'$. After the model is estimated the structure of the model is revised based on model selection procedures and diagnostic tests. The model selection criterion for both models (1) and (2) is based on Lütkepohl's (2005) sequential elimination of regressors. After the full model is estimated, the method sequentially deletes those regressors which lead to the largest reduction of the AIC until no further reduction is possible (only a single regressor is eliminated in each step). Diagnostic tests also are performed on the restricted model. We perform the Portmanteau test for autocorrelation, ACF of the residual for each equation, univariate and multivariate Jarque-Bera tests for normality, and univariate and multivariate ARCH-LM for heteroscedasticity.

To assess the interdependencies among agricultural commodities, crude oil, and macroeconomic factors we compute impulse responses. The impulse response over time shows the behaviour of each variable when shocks of other variables enter into the system. The response to shocks is

examined using the vector moving average (VMA) representation of the VAR. In the VMA, the price series are a function of current and past values of the shocks.

$$\Delta p_t = \Phi_0 u_t + \Phi_1 u_{t-1} + \Phi_2 u_{t-2} + ..., \quad (3)$$

Alternatively, the VMA process may be expressed in terms of s periods in the future,

$$\Delta p_{t+s} = \Phi_0 u_{t+s} + \Phi_1 u_{t+s-1} + \Phi_2 u_{t+s-2} + ..., \quad (4)$$

where $\Phi_0 = I_K$, $\Phi_s = \sum_{j=1}^{s} \Phi_{s-j} A_j$, s = 1, 2, ...,

The components of u_t may be instantaneously correlated (i.e. Σu is not diagonal) and in such cases computing orthogonalized shocks is more appropriate (Sims 1980). Using a Choleski decomposition, the orthogonalized shocks are $\varepsilon_t = P^{-1} u_t$, where P is a lower triangular matrix such that $\Sigma u = PP'$. Equation (4) can now be re-written as,

$$\Delta p_{t+s} = \Psi_0 \varepsilon_{t+s} + \Psi_1 \varepsilon_{t+s-1} + \Psi_2 \varepsilon_{t+s-2} + ..., \quad (5)$$

where $\Psi_0 = P$, $\Psi_s = \Phi_s P$, and the elements of the matrices Ψ_s are given by:

$$\Psi_s = \begin{matrix} \psi_{11}^s & \psi_{12}^s & \cdots & \psi_{1K}^s \\ \psi_{21}^s & \psi_{22}^s & & \psi_{2K}^s \\ \vdots & & \ddots & \vdots \\ \psi_{K1}^s & \psi_{K2}^s & \cdots & \psi_{KK}^s \end{matrix} . \quad (6)$$

Each off-diagonal element of the matrix Ψ_s represents the response of prices of one variable (i.e, an agricultural commodity) to innovations of another variable (i.e, a macroeconomic factor). We build the orthogonal impulse response function (IRF) by plotting the elements of Ψ_s as a function of s. For example, the coefficient ψ_{32}^1 represents the one period ahead response of variable 3 to innovations of variable 2. An orthogonal impulse response plot of variable 3 to innovations of variable 2 contains the coefficients ψ_{32}^1, ψ_{32}^2, ...

Because P is a lower diagonal matrix, a shock of the first variable in the system will have an instantaneous impact on all the rest of the variables, but shocks of subsequent variables will only have an instantaneous impact on the remaining variables in the system. An important consequence of this is that different orderings of the variables in the vector Δp_t yield different impulse responses. We therefore use an ordering where the most influential variable, i.e. the macroeconomic factor, is placed first. When the order is not clear using economic intuition we perform preliminary testing using different orderings and we compare the impact coefficients' sign and the shape of the impulse response function for each ordering.

The impulse response analysis for the VEC model in equation (2) is performed in a similar manner. The VEC model is first written in VAR levels form (see Lütkepohl 2005, p. 289). The orthogonal impulse response coefficients, ψ_{kk}^s, are then computed using equations (4) and (5). Note that these impulse response coefficients are computed from a VAR in levels, whereas those from equation (1) come from a VAR in differences. The shape of the impulse response function is therefore different depending on the underlying data. If the variables in the model are stationary the impulse responses converge to zero as time (s) increases; however if the price

series are non-stationary and cointegrated, shocks to the system may have permanent effects and the impulse response coefficients may not converge to zero as *s* increases (Breitung, Brüggemann, and Lütkepohl 2004). The 95% confidence intervals for the impulse responses are computed using bootstrap methods. We follow the standard percentile interval method as described in Breitung, Brüggemann, and Lütkepohl (2004) with 1000 bootstrap residuals.

The forecast error variance decomposition (FEVD) is the percentage contribution of variable *i* to the *h*-step forecast error variance of variable *k*. To compute the FEVD we follow Breitung, Brüggemann, and Lütkepohl (2004). The FEVD, ω_{ki}, is given by,

$$\omega_{ki}(h) = \left(\psi^2_{ki,0} + \cdots + \psi^2_{ki,h-1}\right) / \sigma^2_k(h)$$

where $\sigma^2_k(h) = \sum_{i=1}^{K}\left(\psi^2_{ki,0} + \cdots + \psi^2_{ij,h-1}\right)$ is the variance of the forecast error. The impulse responses, their corresponding confidence intervals, and the FEVD are computed using JMulTi.[1]

Data

For the analysis we use average weekly cash prices for all commodities. Corn (C) cash prices are for central Illinois. Wheat (W) cash prices are for St. Louis. For hogs (LH), we use producer sold negotiated (carcass basis) purchase cash prices from the USDA Iowa/Minnesota Daily Hogs report (LM_HG206). For cattle (LC), we use Texas/Oklahoma prices. Crude oil (CL) is West Texas Intermediate which is commonly used in the U.S. as a benchmark in oil pricing (and it's the underlying commodity of the former New York Mercantile Exchange's oil futures contracts). Ethanol (ET) prices come from the USDA. Iowa ethanol prices are the longest series, however the series only starts in 2005. For the exchange rate we use the U.S. dollar index (DX) which represents the value of the U.S. dollar relative to a basket of world currencies, including the Euro, the Japanese yen, the British pound, the Canadian dollar, the Swiss franc, and the Swedish krona. The DX trades in the Intercontinental Exchange (ICE, former NYBOT). All data except for ethanol are from the Commodity Research Bureau.

All price series for the period January 1998-November 2009 are plotted in Figures 1 to 3. Grain and oil prices increase well above historical values starting in late 2006. Starting in 2002, the US dollar index gradually declines (representing a reduction in the value of the dollar), reaching its lowest point in mid 2008 which coincides with the highest crude oil price. Cattle and hogs prices increase through time, but during the last ten years their increases have not been as dramatic as those seen in the grains (Figure 2).

Results

According to the Zivot-Andrews test results for the corn series the most likely point of break is September 2006. We use the results for the corn price series because crop markets which

[1] JMulTi is published under the General Public License. It is available for free from www.jmulti.com.

experienced major price changes are central in our analysis. We define two periods, before and after the break point: period 1 is from January 1998 to mid-September 2006, and period 2 is from mid-September 2006 to November 2009.

Table 1 shows the unit root test statistics for both periods.[2] For period 1, oil and exchange rate appear to be non-stationary, and wheat's test statistic differs from the critical value only at the second decimal. All three variables are stationary in differences. For period 2, all variables are integrated of order 1. Table 2 shows the trace statistics and critical values of the rank test for each period. For period 1 we fail to reject the null hypothesis of no cointegrating vector, whereas for period 2 we reject the null for no cointegrating vector but fail to reject the null of one cointegrating vector. Based on these results we estimate a VAR model for period 1 and a VEC model for period 2.

Using the AIC criteria and diagnostic tests we estimated both the VAR and VEC models with 3 lags of each variable. The VAR model was estimated in log differences and the VEC model was estimated in logs.[3] For period 1, parameter estimates for the terms not eliminated by the sequential procedure are shown in Table 3. Markets predominately appear to be affected by the lags in their own prices, and exchange rate and oil price have only limited effects on agricultural markets. Exchange rates influence corn prices, while oil prices affect wheat prices. Somewhat unexpectedly corn and lean hog prices influence exchange rates, and wheat prices influence oil prices. While statistically significant, the magnitudes of the coefficients for these unexpected effects are not large and considerably smaller on a percentage basis than the exchange rate effect on corn which represented the largest macro-variable effect on agricultural commodity prices. Table 3 also identifies the interrelationships among agricultural markets. As expected, corn has a positive and significant effect on live cattle reflecting feed use. Wheat and lean hog prices also appear to be related, with lagged live hog prices influencing wheat prices and vice-versa.

For period 2 parameter estimates of the VEC model are presented in Table 4. The effect of own lags in the agricultural markets is reduced relative to the first period and is non-existent for lean hogs. A new relationship between exchange rates and oil has emerged as they both enter significantly in the long-run vector and are influenced in the short-run by lagged values of the other variable. The short-run exchange rate effect on corn is more pronounced relative to period 1, and the effect of oil on agricultural markets is stronger and more widespread. For instance, the oil effects on corn and lean hogs were not present in period 1, and a more significant coefficient for wheat is exhibited. The short-run effect of agricultural markets on the exchange rate has disappeared, except for corn with a coefficient that is small and only significant at the ten percent level. Instead, we find significant short-run effects from corn and live cattle to oil which may be related to changes in energy use of corn related to biofuel mandates and an enhanced competition for corn. While ethanol doesn't have significant effects on oil, corn, and livestock, the variable was not eliminated by the sequential procedure indicating the presence of ethanol price enhanced the overall performance of the model. The results in Table 4 also show some changes in the

[2] To facilitate comparisons, prices were transformed to logarithms prior to estimation.

[3] Misspecification tests for both periods exhibited no autocorrelation for the estimated relationships. However, normality and ARCH-type tests were clearly rejected particularly in period 1.

interrelationships among agricultural markets. For period 2 there is no direct effect from corn to live cattle, and effects from corn to lean hogs and from cattle to wheat have emerged.

The orthogonal IRFs represent the effect of a shock equivalent to a one standard deviation increase of a macro variable (exchange rate and oil prices) on the agricultural commodities. Figure 4 and Figure 5 provide the effects of exchange rate and oil for period 1. Figure 7 and Figure 8 present the same effects for period 2. However, the magnitudes of the IRFs for the two periods are not directly comparable. As identified earlier, the IRFs for the VAR model (period 1) represent the log differenced effects whereas the IRFs for the VEC model (period 2) were transformed into log levels to reflect the cointegration relationship in the system. As a result, we focus on how the relationships have changed in the second period and the new factors influencing agricultural prices. Preliminary analysis using different orderings of the variables in both the VAR and VEC models were conducted. When commodity prices appear first the IRFs have unexpected signs and patterns; however when either the exchange rate or the crude oil price appear first the IRF obtained have the expected signs and similar patterns.

For period 1, a positive shock of a one standard deviation increase in the exchange rate (Figure 4), which would reflect a more expensive US dollar relative to other currencies, leads to immediate declines in corn and wheat prices followed by increases which quickly die out after five or six weeks. Cattle prices are hardly influenced by exchange rates, and along with wheat prices have zero within 95 percent confidence intervals, indicating the effects are not significantly different from zero. Hog prices demonstrate a pattern opposite to corn, with an initial increase, followed by a decline, but these movements are not significantly different from zero. In contrast, in corn the exchange rate effect is significantly different for the first two weeks at the five percent level.

The effect of oil prices on agricultural commodities (Figure 5) during this period moves in the expected direction, although not significant. Point estimates for all commodities indicate an initial increase of agricultural prices that quickly die out in less than four weeks. An increase in oil prices is transmitted to agricultural markets via increases in production costs.

For period 2, the effect of the exchange rate is larger in the grain relative to the livestock markets (Figure 7). In both corn and wheat, a shock of a one standard deviation increase in the exchange rate leads to an initial decrease in prices that is significant at the five percent level. In corn, point estimates move apart from equilibrium levels; they continue to decrease and seem to stabilize at about four percent below the initial equilibrium price after approximately sixteen weeks. After the second week, however, the upper limit of the confidence interval falls slightly above zero, making it difficult to draw strong conclusions on the effect of exchange rates on corn price. In wheat, prices move towards the initial equilibrium price after the shock. Here, again prices are not significantly different from zero after the second week. In livestock markets, point estimates seem to be below the equilibrium price; however the effect is small and not significant.

The effects of an oil price shock (Figure 8) during this period are similar to those in period 1, although in wheat the initial increase in prices is now significant. Corn, wheat, and cattle prices seem to return to equilibrium levels after the initial shock. In hogs, even though not statistically

significant, prices move apart from the equilibrium and stabilize at about two percent below the initial equilibrium prices.

The FEVD is used to decompose the variance of each series into the percentages attributable to each innovation. Figure 6 and Figure 9 show the FEVD for period 1 and period 2 respectively. In each figure, each color represents a different market. For example, in Figure 6 a) most of the forecast variance in corn can be explained by its own innovations. In Figure 6 b), the forecast variance in wheat is mostly explained by its own innovations; however the contribution of corn to the wheat forecast error variance is about twenty three percent. Other than this contribution, the forecast errors in the rest of the markets for period 1 are largely attributable to own innovations. In contrast, for period 2, exchange rate innovations enter in most markets. The major effect of exchange rate is in the forecast error variance decomposition of corn, especially at longer-term forecast horizons. The contribution is between twelve to twenty five percent. In wheat, the contribution of corn decreases and the contribution of exchange rate increases with respect to period 1. In cattle the contribution of the exchange rate is small and in hogs it reaches sixteen percent in the 20^{th} week. To a much lesser extent, innovations in oil prices have a larger effect in the forecast errors of period 2, especially in livestock markets. In cattle and hogs the contribution reaches five and eight percent respectively, whereas in corn and wheat is one and two percent respectively.

Conclusions

Rising commodity prices in the last few years have generated much debate among researchers, analysts, and market participants. The increase has been attributed by some to the presence of a structural break, suggesting that new relationships among the different markets may have emerged. Here we estimate the linkages among agricultural commodities, oil, and exchange rates in the new market environment.

First we identified the point of break and perform the analysis for each period, before and after the observed rise in prices. For the first period, from 1998 to 2006, the estimated VAR model indicates that exchange rate and crude oil have limited effect on agricultural markets, which appear to be most affected by the lags in their own prices. For the second period, from 2006 to 2009, the estimated VEC model indicates that the effect of own lags in the agricultural markets are smaller and the effect of the exchange rate and crude oil are more pronounced, especially in the corn market.

We also estimated impulse response functions from exchange rate and oil to agricultural commodities, and the forecast error variance decomposition for each agricultural commodity. For period 1, point estimates of the effect of a shock of exchange rate leads to a decrease and then an increase in corn, wheat, and cattle prices which quickly die out after five or six weeks. However the price movements are not significant at conventional levels. In contrast, for period 2, a positive shock of the exchange rate leads to an initial significant decrease in the crop prices. In corn, although not statistically significant, prices seem to stabilize at about four percent below the initial equilibrium price after approximately sixteen weeks. The effect on livestock markets is much smaller. A shock of oil prices for period 1 also leads to price movements in the expected

direction, although not significant at the five percent level. For period 2 the effect in the wheat market is significant. The results suggest that an increase in oil prices is transmitted to agricultural markets via increases in production costs.

Finally, the FEVD suggests that the proportion of the movements in commodity markets forecast errors have changed. While for period 1 the proportion of movements is mainly influenced by own market shocks, for period 2 the proportion attributable to shocks of the exchange rate has increased, especially in the corn market where the contribution varies between twelve to twenty five percent. Shocks from oil prices also contribute to explain agricultural commodities forecast errors for period 2, although the effect is smaller between one to two percent for grains and roughly six percent for livestock. On balance, the overall results suggest that the linkages among agricultural commodities, and more macroeconomic variables such as exchange rates and oil prices have increased. In recent periods, agricultural commodity markets appear to more dependent on exchange rates and to a lesser extent on oil prices.

References

Bessler, D. A., and R. A. Babula. "Forecasting Wheat Exports: Do Exchange Rates Matter?" *Journal of Business and Economic Statistics* 5(1987):397-406.

Bradshaw, G. W., and D. Orden. "Granger Causality from the Exchange Rae to Agricultural Prices and Export Sales." *Western Journal of Agricultural Economics* 15(1990):100-110.

Breitung, Brüggemann, and Lütkepohl. "Structural Vector Autoregressive Modeling and Impulse Responses," in H. Lütkepohl and Krätzig (eds), *Applied Time Series Econometrics*, 2004.

Chen, Yu-chin, Rogoff, Kenneth S. and Rossi, Barbara (2008). "Can Exchange Rates Forecast Commodity Prices?" Economic Research Initiatives at Duke (ERID) Working Paper No. 1. Available at SSRN: http://ssrn.com/abstract=1183164.

Enders, W. "Applied Econometric Time Series." Wiley Series in Probability and Statistics, 2000.

Frank, J. and P. Garcia. "Time-varying Risk Premium: Further Evidence in Agricultural Futures Markets." *Applied Economics* 41(2009):715-725.

Harri, A., L. Nalley, and D. Hudson. "The Relationship between Oil, Exchange Rates, and Commodity Prices." *Journal of Agricultural and Applied Economics* 41(2009):501-510.

Lütkepohl, H. "New Introduction to Multiple Time Series Analysis." Springer-Verlag, Berlin, 2005.

Lütkepohl, H. "Vector Autoregressive and Vector Error Correction Models" in H. Lütkepohl and Krätzig (eds), *Applied Time Series Econometrics*, 2004.

McCalla, A. "World Food Prices: Causes and Consequences." *Canadian Journal of Agricultural Economics* 57(2009):23-34.

Park, H., and T. R. Fortenbery (2007). "The Effect of Ethanol Production on the U.S. National Corn Price." *Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

Schuh, G. E. "The Exchange Rate and U.S. Agriculture." *American Journal of Agricultural Economics* 56(1974):1-13.

Sims, C. "Macroeconomics and Reality." *Econometrica* 481(1980):1-48.

Tejeda, A. T., and B. K. Goodwin (2009). "Price Volatility, Nonlinearity and Asymmetric Adjustments in Corn, Soybean and Cattle Markets: Implication of Ethanol-driven Shocks." *Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. St. Louis, MO. [http://www.farmdoc.uiuc.edu/nccc134].

Tomek, W. "Commodity Futures Prices as Forecasts." *Review of Agricultural Economics* 19 (1997):23-44.

Yeboah, O., S. Shaik, and A. Allen. "Exchange Rates Impacts on Agricultural Inputs Prices using VAR." *Journal of Agricultural and Applied Economics* 41(2009):511-520.

Zivot, E. and D. Andrews. "Further Evidence on the Great Crash, the Oil-price Shock, and the Unit-root Hypothesis." *Journal of Business & Economic Statistics* 10(1992):251-70.

Table 1: Augmented Dickey Fuller unit root test

	Period 1				Period 2			
	Model	Lags	5% crit. value	τ-stat	Model	Lags	5% crit. value	τ -stat
C	CNT	1	-2.872	-3.153	CNT	3	-2.886	-2.216
ET					CNT	2	-2.886	-1.910
W	CT	3	-3.422	-3.459	CT	1	-3.442	-1.781
LC	CT	7	-3.422	-4.765	CNT	3	-2.886	-1.872
LH	CT	1	-3.422	-4.146	CNT	3	-2.886	-2.650
CL	CT	3	-3.422	-2.759	CNT	8	-2.886	-2.328
DX	CT	2	-3.422	-1.582	CNT	4	-2.886	-1.729
Δ*C*	NCNT	1	-1.950	-15.122	NCNT	2	-1.950	-6.246
Δ*ET*					NCNT	1	-1.950	-7.128
Δ*W*	NCNT	2	-1.950	-13.622	NCNT	1	-1.950	-8.450
Δ*LC*	NCNT	8	-1.950	-6.398	NCNT	2	-1.950	-8.084
Δ*LH*	NCNT	1	-1.950	-13.765	NCNT	1	-1.950	-8.533
Δ*CL*	CNT	6	-2.872	-9.447	NCNT	2	-1.950	-5.526
Δ*DX*	NCNT	1	-1.950	-13.724	NCNT	3	-1.950	-6.261

CT: constant and trend, CNT: constant and no trend, NCNT: no constant and no trend. The variable acronyms are: *C*—corn price; *ET*—ethanol price; *W*—wheat price; *LC*—live cattle; *LH*—lean hogs; *CL*—crude oil; and DX—exchange rate. The variables are described in the text.

Table 2: Rank test

Rank	Trace statistic	5% critical value
Period 1		
0	90.44	94.15
1	53.02	68.52
2	31.29	47.21
Period 2		
0	98.10	94.15
1	61.93	68.52
2	39.07	47.21

Table 3: Restricted VAR model for period 1, January 1998 - September 2006

	Equation											
	ΔDX		ΔCL		ΔC		ΔW		ΔLC		ΔLH	
ΔDX_{t-1}	0.270	***	0.316									
ΔDX_{t-2}					0.223	*					-0.467	
ΔCL_{t-1}			0.169	***							0.107	
ΔCL_{t-2}			-0.115	**			-0.064	*				
ΔCL_{t-3}			0.100	**								
ΔC_{t-1}	0.038	***			0.161	***			0.075	**		
ΔC_{t-2}			-0.107		-0.081	*						
ΔW_{t-1}			0.140	**			0.091	**				
ΔW_{t-2}							-0.068				-0.207	**
ΔW_{t-3}							-0.064				0.165	*
ΔLC_{t-1}									0.227	***		
ΔLC_{t-2}									-0.265	***		
ΔLC_{t-3}									0.076		-0.193	
ΔLH_{t-1}							-0.041	*			0.295	***
ΔLH_{t-3}	0.010	*			0.028						-0.101	**
Constant			0.03						0.001		0.001	

Significance: 1% (***), 5% (**), and 10% (*). The variable acronyms are defined in Table 1.

Table 4: Restricted VECM model for period 2, September 2006 – November 2009

	Equation													
	ΔDX		ΔCL		ΔC		ΔET	ΔW		ΔLC		ΔLH		
α	-0.065	**	-0.520	***	-0.204		0.017	-0.003		0.002		-0.411	***	
β	1		0.197	***	0.019		-0.109	-0.026	*	0.073		-0.029		
ΔDX_{t-1}	0.259	***	0.745	**	0.528	**								
ΔCL_{t-1}			0.154	**						0.038		0.112	*	
ΔCL_{t-2}			-0.136	**	-0.049			-0.205	***					
ΔCL_{t-3}	-0.051	***	0.273	***	0.160	***	0.126	0.124				-0.096		
ΔC_{t-1}	-0.028	*			0.235	***	0.188							
ΔC_{t-2}			0.302	***										
ΔC_{t-3}												0.188	**	
ΔET_{t-1}							0.323			0.092		-0.220		
ΔET_{t-3}			-0.213		-0.092									
ΔW_{t-1}								0.149	**					
ΔW_{t-3}												-0.119	*	
ΔLC_{t-1}										0.192	***			
ΔLC_{t-2}			0.382	**						-0.263	***			
ΔLC_{t-3}								-0.501	**					
ΔLH_{t-1}												0.114		

Significance: 1% (***), 5% (**), and 10% (*). The variable acronyms are defined in Table 1.

Figure 1: Corn and wheat cash prices, January 1998 - November 2009

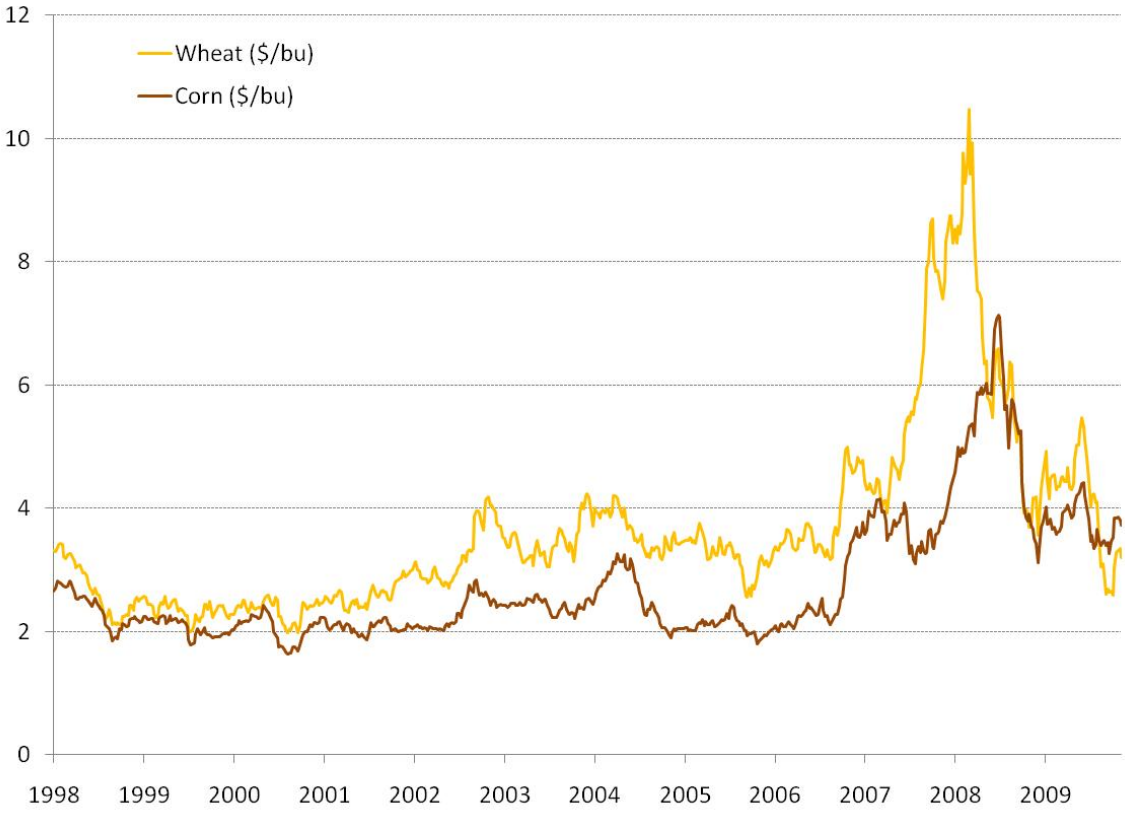


Figure 2: Cattle and hogs cash prices, January 1998 - November 2009

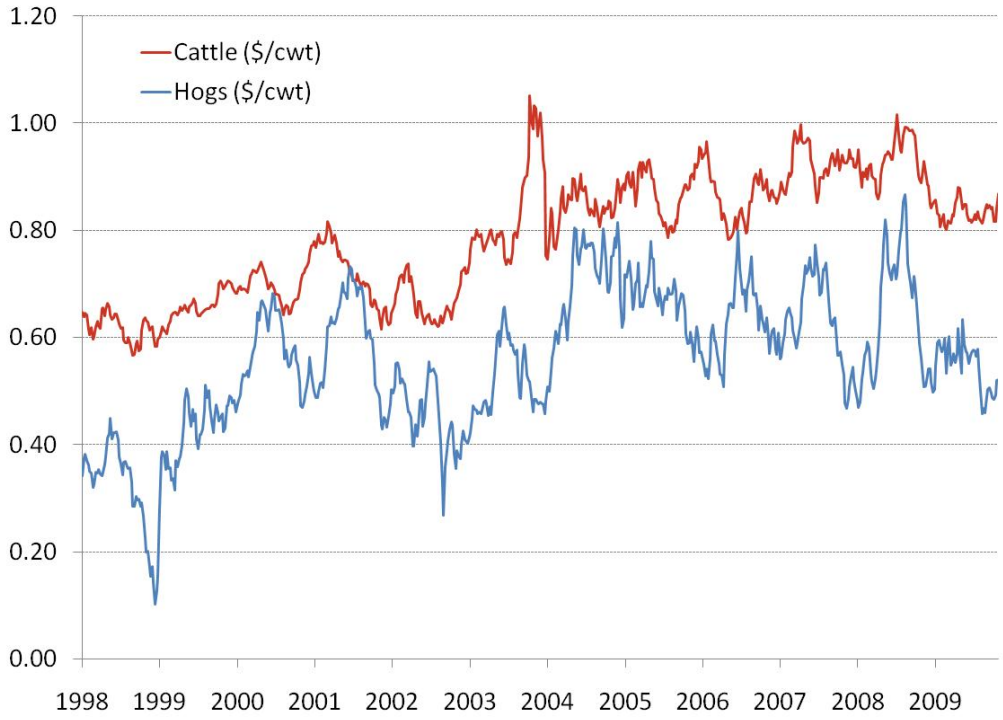


Figure 3: Crude oil prices and the US dollar index, January 1998 - November 2009

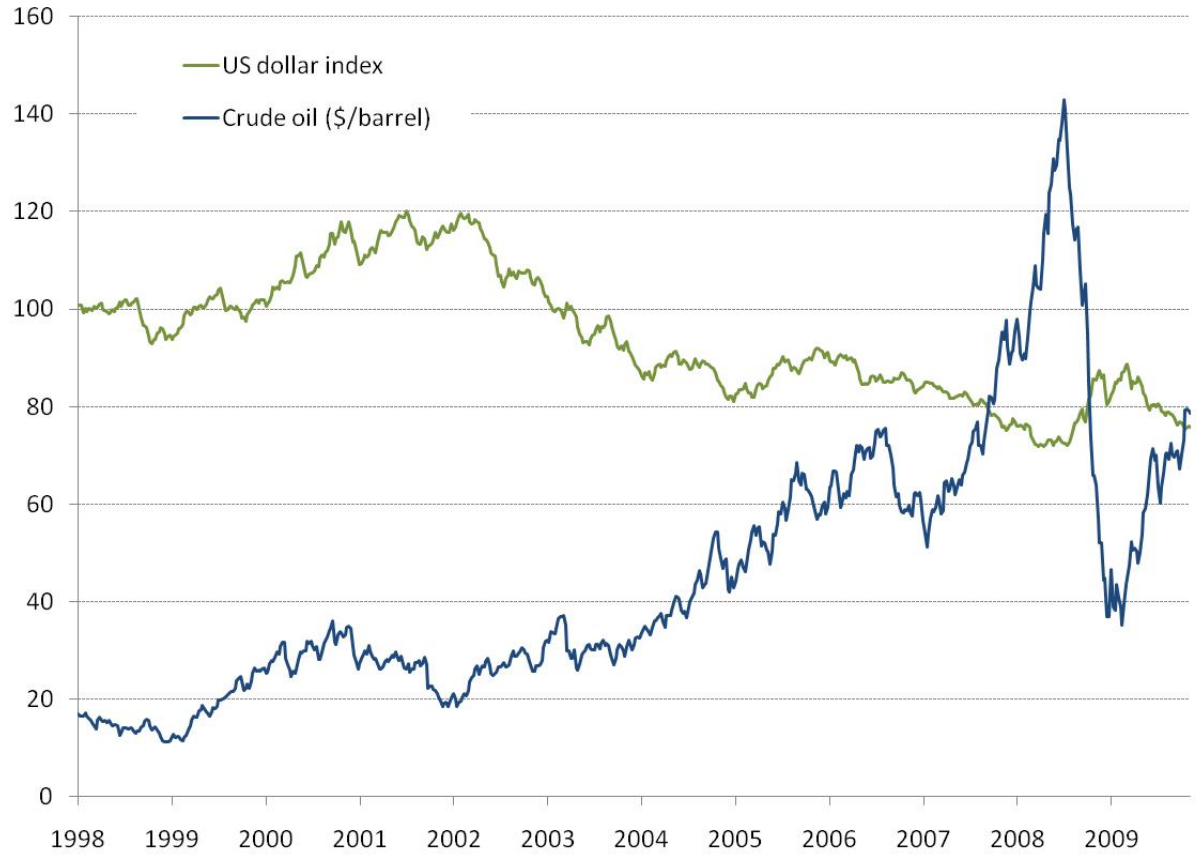
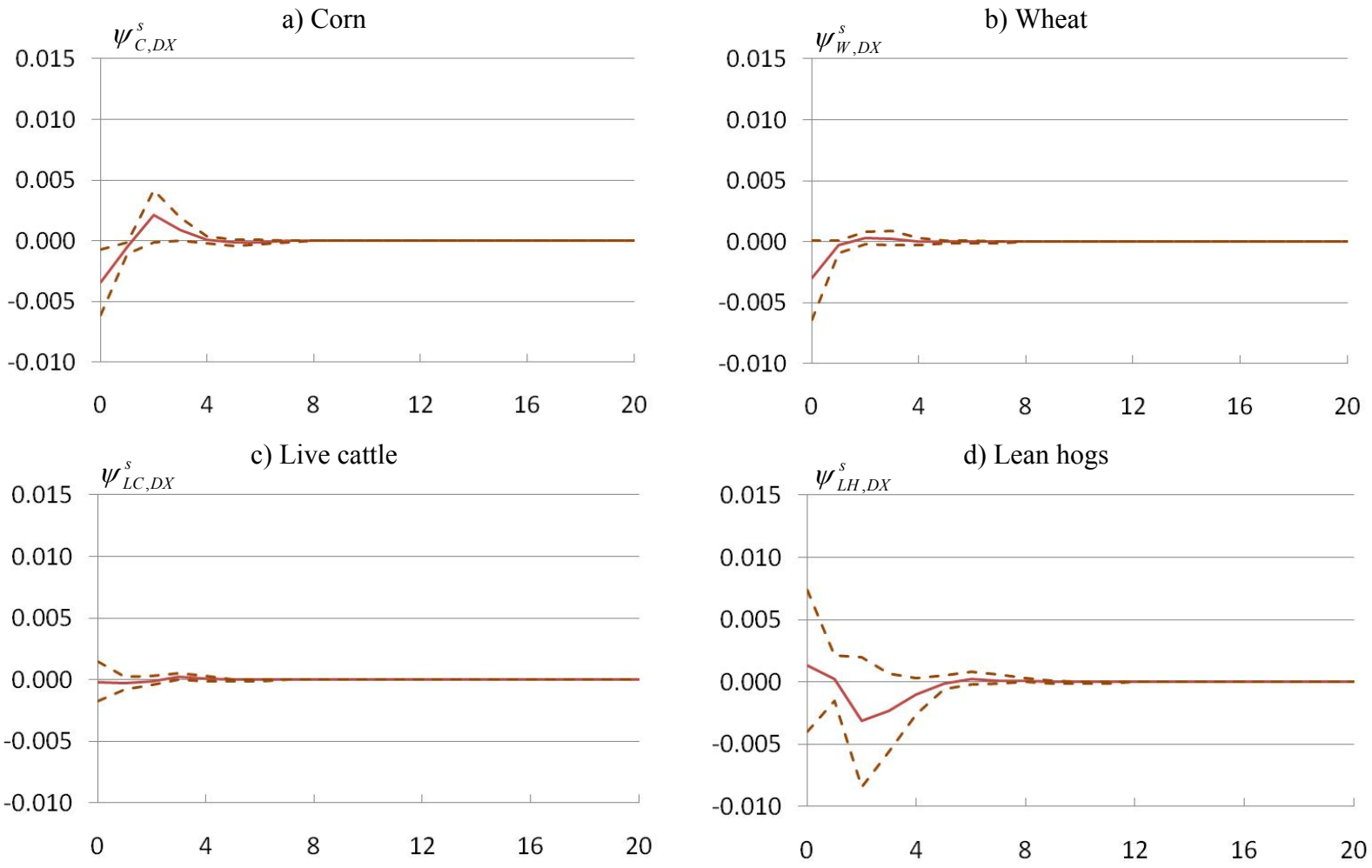
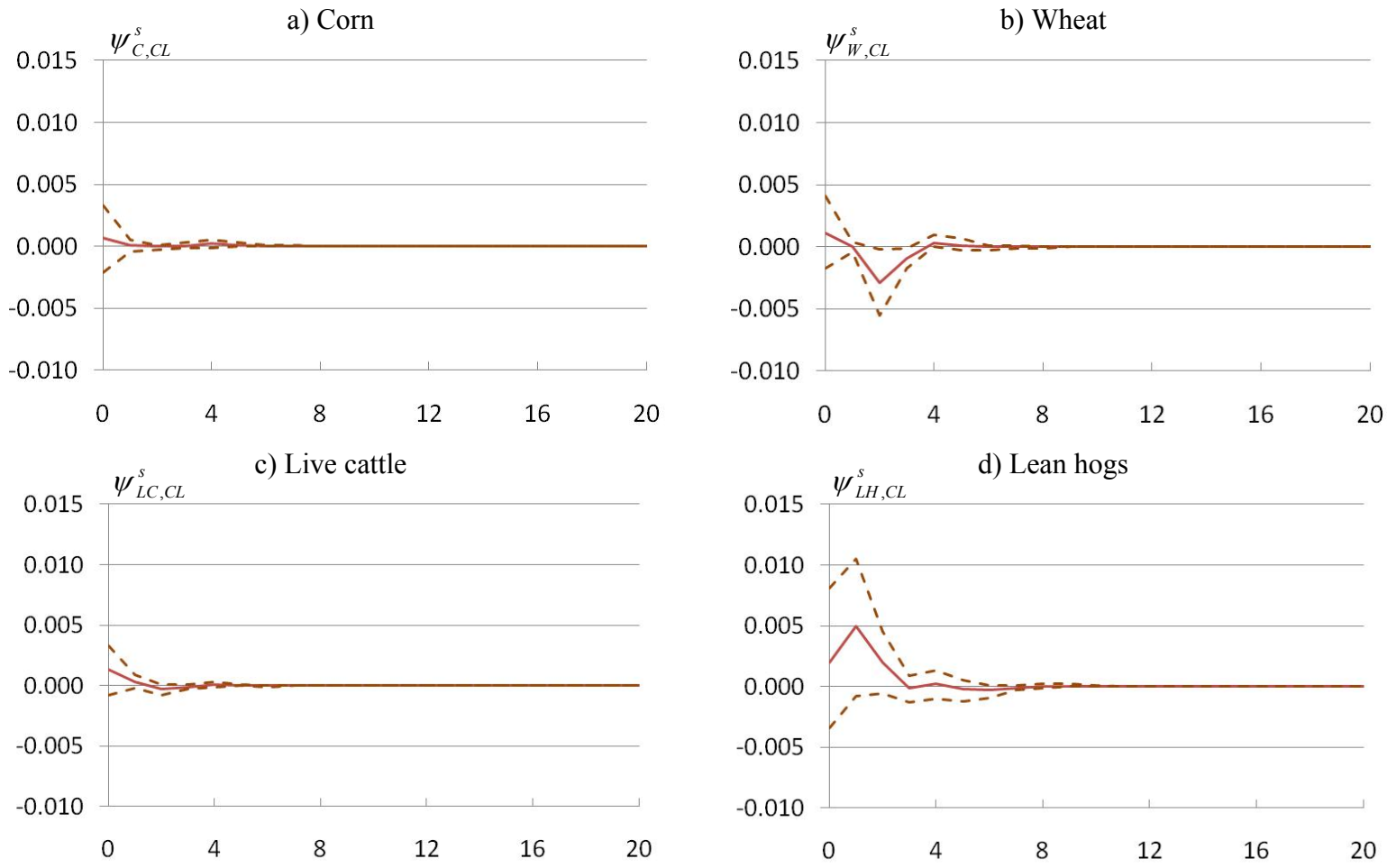


Figure 4: Impulse response to exchange rate – period 1, January 1998 - September 2006



The horizontal axes show future time periods, *s*. The dotted line represents 95% confidence intervals.

Figure 5: Impulse response to crude oil – period 1, Janurary 1998 - September 2006



The horizontal axes show future time periods, *s*. The dotted line represents 95% confidence intervals.

Figure 6: Forecast error variance decomposition – period 1, January 1998 - September 2006

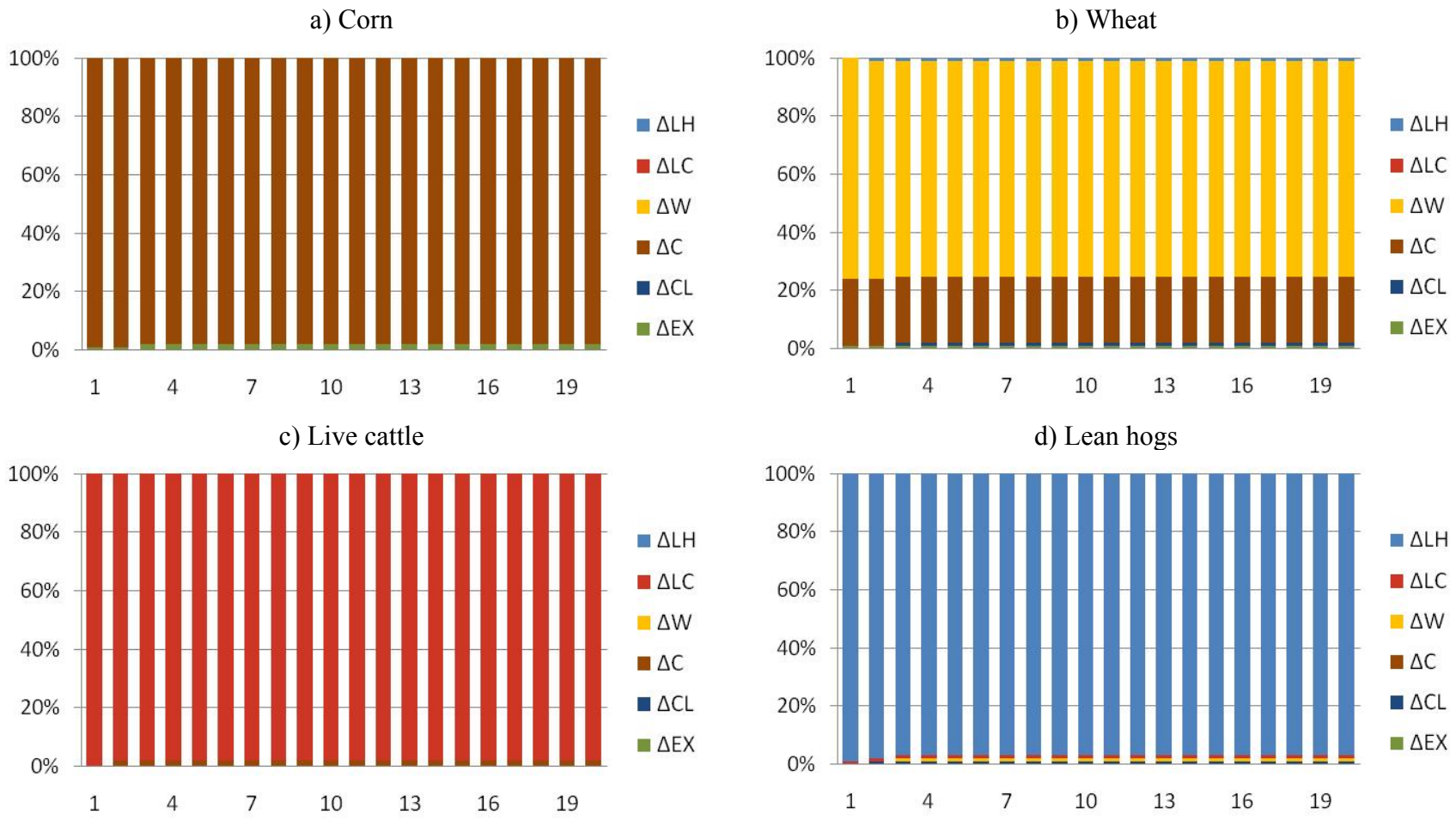
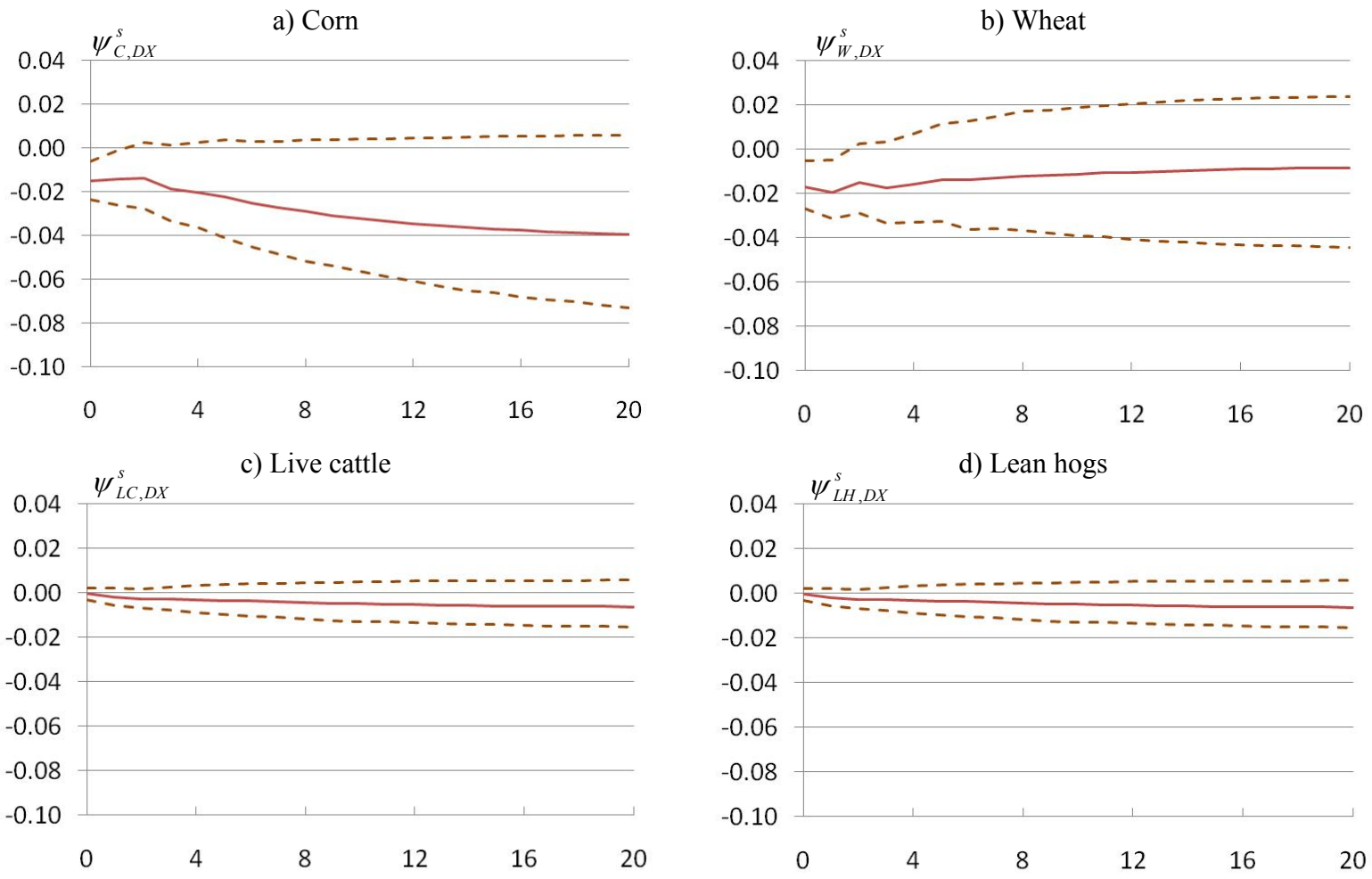
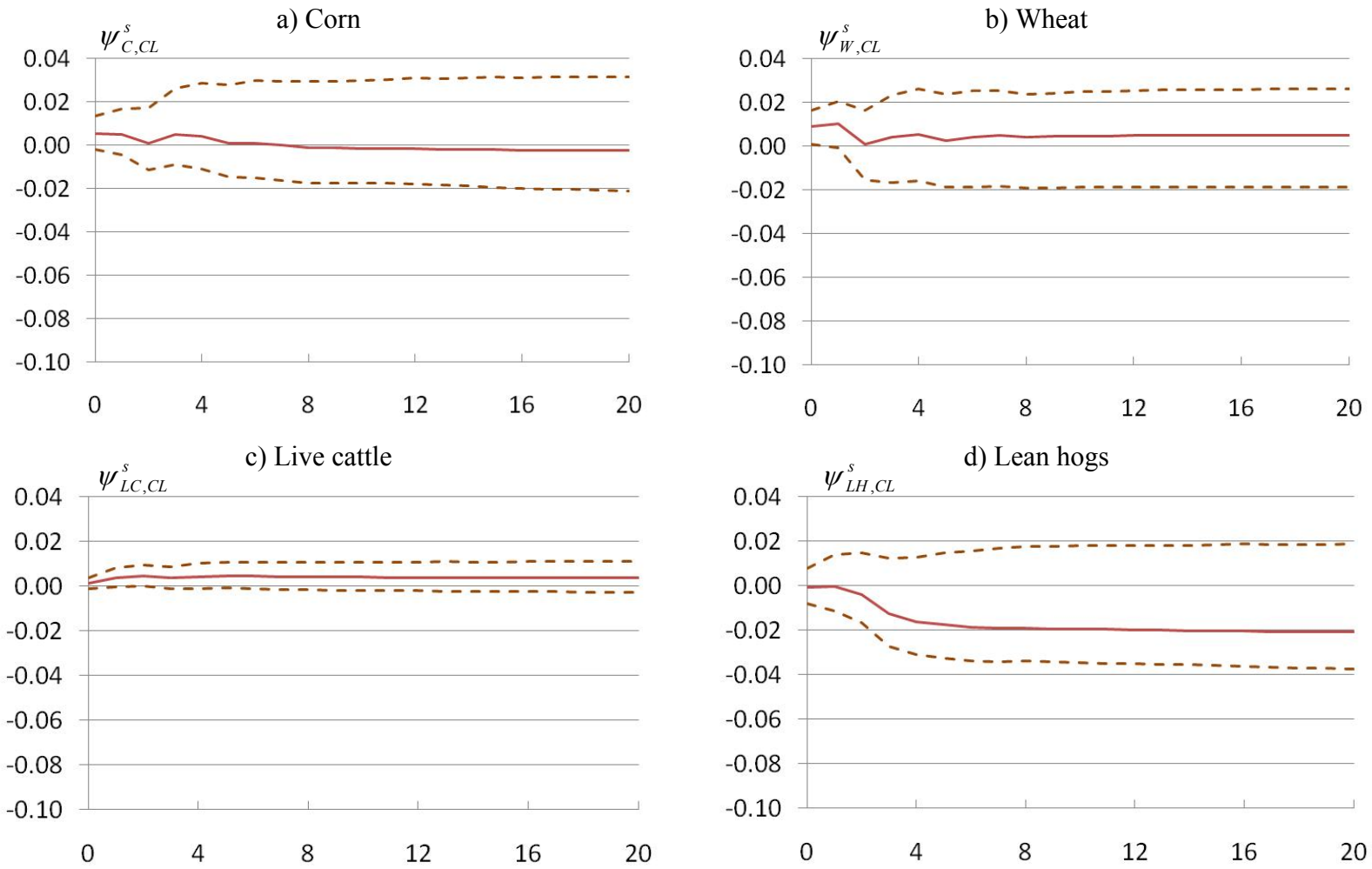


Figure 7: Impulse response to exchange rate – period 2, September 2006 - November 2009



The horizontal axes show future time periods, *s*. The dotted line represents 95% confidence intervals.

Figure 8: Impulse response to crude oil – period 2, September 2006 - November 2009



The horizontal axes show future time periods, *s*. The dotted line represents 95% confidence intervals.

Figure 9: Forecast error variance decomposition – period 2, September 2006 - November 2009