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# CAUSAL RELATIONSHIPS BETWEEN GRAIN, MEAT PRICES AND EXCHANGE RATES

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**Abstract**

*Understanding agricultural commodity price relationships are important as they help producers improve their awareness regarding production costs and ultimately aid in income determination. The present paper empirically examines the dynamic interrelationships among grain, meat prices and the U.S. dollar exchange rate. Johansen cointegration tests reveal no cointegrating relationships among the study variables. Majority of the commodities studied in the paper exhibited unidirectional causality except for corn and lean hogs. The vector autoregression (VAR) model results indicate that the grain and meat prices are influenced by their own past prices. The role of exchange rates is found to be limited in linking the agricultural commodities.*
**Keywords:** *Causality, Cointegration, Exchange Rates, Grain and Meat Prices, VAR.*
**JEL Codes:** *C58; G10; Q11; Q13;*

## 1. Introduction

Recent increases in commodity prices to unprecedented levels and the global financial crisis in 2008 have prompted governments and policy makers to increase their focus on commodity markets. Hongpeng et al. (2012) reported that during the decade of July 2001 to June 2011, grain prices have increased approximately three fold. Irwin and Good (2009) reported that there is compelling evidence that a new era of volatility and higher crop price levels have begun affecting the commodity markets. The authors believe that the higher commodity prices are the new norm and would stay at elevated levels for the near future. The magnitude of changes in price levels of agricultural commodities are typically affected by supply and demand variables such as the impact of adverse weather conditions, prices of substitutes, diversion of grain crops to meet energy needs and changes in food consumption behavior.

Grain prices like corn influence livestock production through input prices. Corn is typically used as animal feed in the United States and fluctuations in corn prices could affect the demand for corn originating from the livestock sector. Zhang and Reed (2008) opined that biofuel production is driving up the cost of production of corn and other feed grains, and ultimately contributing to the rise of meat prices, especially pork. Fluctuations in currency exchange rates could affect both agricultural producers and consumers in a trade dependent economy. For example, depreciating currency makes exports more attractive to the farmers; whereas currency appreciation makes imports more attractive to the consumers. According to Schuch (1974), changes in the value of the dollar could influence the commodity prices and in turn affect the competitiveness of U.S. agricultural commodities in the world market. Hence it is reasonable to expect that there exists a direct linkage between grain and meat prices and an indirect linkage from the effects of exchange rates. Understanding food price volatility especially grain and meat prices and their linkages are important both for producers and consumers. Producers are affected by increased costs of production, and return uncertainty whereas consumers face continually upward spiraling food prices at the retail level.

Majority of the studies pertaining to commodity price relationships in agriculture typically focus on cointegration between grain and crude oil prices (See Campiche et al. 2007; Muhammed and Kebede 2009; Saghaian 2010; Pavel and D'Artis 2011).The findings of the earlier literature reveal a mixed relationship between oil and commodity markets. Some studies reported unidirectional price linkages from crude oil to agricultural commodities citing the development of biofuel sectors the main contributor for linkage (Saghaian, 2010; Hongpeng et al. 2012); while others indicated a bi-directional relationship (Kong et al. 2012; Nazlioglu et al. 2013). Some studies found no relation between the energy and food sector (Campiche et al. 2007; Zhang and Reed, 2008; Yu et al. 2006; Harri and Hudson, 2009). Studies showed that the strength of relationship or the lack of it between crude oil and agricultural commodities largely depended on the commodities of choice (food grains, softs or vegetable oils), and the nature of data (length, frequency) used for the analysis. Very few studies analyzed the effects of exchange rates on grain prices (Abbott et al. 2008; Harri et al. 2009). There is no comprehensive study in the present literature exploring the linkages between grain, and meat prices and exchange rates.

The purpose of the present paper is to understand causal relationships and dynamic interactions among grain, meat prices and the dollar exchange rate by employing a series of econometric tests. First, Augmented Dickey-Fuller (ADF) tests are employed to examine the presence of non-stationarity in the data series. Besides the traditional VAR analysis, this study incorporates impulse response analysis to investigate the dynamic interactions between markets. Granger causality tests are applied to examine the causal structures among the study variables. The outcome of this study would be useful for farmers in properly designing their marketing plans and developing appropriate hedging strategies. Investors and fund managers could benefit from commodity price linkages by creating an optimal portfolio for market returns.

The remainder of the paper is organized as follows: Section 2 deals with the methodological aspects of the price relationships including vector autoregression, cointegration and granger causality. Section 3 describes the nature of data used in the paper, Section 4 deals the results and finally Section 5 concludes the paper.

## 2. Methodology

Multivariate time series models, especially the vector autoregression (VAR) models are commonly used for describing the dynamic behavior of interrelated time series and for forecasting.

### 2.1 Vector Autoregression

VAR approach was first proposed by Sims (1980), as an alternative to simultaneous equation models to the macroeconomic data analysis.

Following Zivot and Wang (2006), let $z_t = \left(z_{1t}, z_{2t}, ..., z_{nt}\right)'$ denote a $\left(n \times 1\right)$ vector of time series variables. The basic *p*-lag vector autoregressive (VAR(*p*)) model takes the following form:

$$z_t = c + \phi_1 z_{t-1} + \phi_2 z_{t-2} + .... + \phi_p z_{t-p} + \varepsilon_t, t = 1, ..., T \tag{1}$$

Where $\phi_i$ are $(n \times n)$ coefficient matrices and $\varepsilon_t$ is an $(n \times 1)$ unobservable zero mean white noise vector process.

A bivariate VAR(2) model when represented in vector form:

$$\begin{pmatrix} z_{1t} \\ z_{2t} \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \begin{pmatrix} \phi_{1,11} & \phi_{1,12} \\ \phi_{1,21} & \phi_{1,22} \end{pmatrix} \begin{pmatrix} z_{1t-1} \\ z_{2t-1} \end{pmatrix} + \begin{pmatrix} \phi_{2,11} & \phi_{2,12} \\ \phi_{2,21} & \phi_{2,22} \end{pmatrix} \begin{pmatrix} z_{1t-2} \\ z_{2t-2} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \tag{2}$$

*or*

$$z_{1t} = c_1 + \phi_{1,11} z_{1t-1} + \phi_{1,12} z_{2t-1} + \phi_{2,11} z_{1t-2} + \phi_{2,12} z_{2t-2} + \varepsilon_{1t}$$

$$z_{2t} = c_2 + \phi_{1,21} z_{1t-1} + \phi_{1,22} z_{2t-1} + \phi_{2,21} z_{1t-1} + \phi_{2,22} z_{2t-1} + \varepsilon_{2t}$$

### 2.2. Johansen Cointegration

Cointegration is considered to be a powerful technique for investigating common trends in multivariate time series. When variables are cointegrated, it implies that the variables have a long term relationship between them. The two commonly used statistical tests for cointegration analysis include the Engle and Granger (1987) approach and Johansen's (1988) multivariate vector autoregression approach. The present paper applies cointegration tests developed by Johansen (1988).

Consider a vector autoregression model, VAR(*p*) for the $(n \times 1)$ vector $z_t$.

$$z_t = \omega D_t + \phi_1 z_{t-1} + .... + \phi_p z_{t-p} + \varepsilon_t, t = 1, ...., T \tag{3}$$

Where $Z_t$ is a vector of non-stationary I(1) variables, $D_t$ represents deterministic terms (constant, trend, seasonal dummies etc.,) and $\varepsilon_t$ represents innovations. The VAR equation in the above can be written in vector error correction form by subtracting $Z_{t-1}$ from both sides:

$$\Delta z_t = \omega D_t + \phi z_{t-1} + \Gamma_1 \Delta z_{t-1} + ..... + \Gamma_{p-1} \Delta z_{t-p+1} + \varepsilon_t \tag{4}$$

*Where* $\phi = \phi_1 + .... + \phi_p - I_n$ *and* $\Gamma_k = -\sum_{j=k+1}^{p} \phi_j, k = 1, ..., p-1$

The number of cointegrating relations (*r*) can be calculated using Johansen's Trace statistic. The statistic is given by:

$$LR_{trace}(r_0) = -T \sum_{i=r_0+1}^{n} \ln\left(1 - \hat{\lambda}_i\right) \tag{5}$$

Where *T* is the number of observations and $\lambda_i$ are the eigenvalues.

### 2.3. Granger Causality

In order to evaluate the nature of relationship between grain, meat prices and exchange rates, Granger causality tests (1988) were employed. The purpose of Granger causality is to evaluate the predictive capacity of a single variable on other variables of the system. Presence of Granger causality offers insights into the nature of commodity returns and can be used as a basis for predicting time series models (Alexander, 2001).For a bivariate system of stationary time series $\{x_t\}$ and $\{y_t\}$, the variable *x* is said to Granger cause *y* if we can better forecast *y* using lagged values of *x*, even after lagged y variables are taken into account.

Following Alexander (2001), consider a VAR (*p*) model for *x* and *y* which can be represented as:

$$x_t = \phi_1 + \sum_{i=1}^{p} \alpha_{1i} x_{t-i} + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \varepsilon_{1t} \tag{6}$$

$$y_t = \phi_2 + \sum_{i=1}^{p} \alpha_{2i} x_{t-i} + \sum_{i=1}^{p} \beta_{2i} y_{t-i} + \varepsilon_{2t} \tag{7}$$

The test for Granger causality from *x* to *y* is an F test for the joint significance of $\alpha_{21,}....,\alpha_{2p}$. Similarly, the test for Granger causality from *y* to *x* is for the joint significance of $\beta_{11,}....,\beta_{1p}$.

## 3. Data

Futures price data used in the present paper include monthly settlement prices for corn, live cattle and lean hogs for the period of January 1993 to December 2016. The present study used continuous futures prices calculated from the settlement prices in order to eliminate price distortions caused by price gaps between expiring contracts and the next futures contracts. Corn is traded on the Chicago Board of Trade (CBOT), whereas live cattle and lean hogs are traded on the Chicago Mercantile Exchange (CME). Exchange rate data used in the study is the trade weighted average of the value of the U.S. dollar against major currencies of U.S. trading partners. Overall, the study sample comprises of 288 observations for conducting the analysis.

## 4. Results

Table 1 reports the descriptive statistics of the variables used in the study: corn, live cattle, lean hogs and exchange rate, while Figure 1 shows the graphical plots of the same variables. The descriptive statistics show the average prices, maximum, minimum values, standard deviation of prices, skewness, kurtosis and Jarque-Bera statistics. The difference between the maximum and minimum values shows the price range of the commodities during the study period. The results show that corn monthly prices ranged from \$1.80/bu. to \$8.06/bu., live cattle prices ranged from \$0.57/lb. to \$1.68/lb.; lean hogs prices varied from \$0.28/lb. to \$1.32/lb. for the length of the study. At the same period, the exchange rate fluctuated from 72.16 to 120.59. The standard deviation measures the risk or volatility associated with the crop returns. The commodity price series display non-zero skewness and excess kurtosis. From Figure 1, it is evident that significant price differences exists among all the four commodities under investigation. Price indices for all the agricultural commodities have risen during the study period; however during the last few years, after witnessing the boom, the commodity prices seem to be softening.

**Table 1. Descriptive Statistics of the Time Series Variables**

| Statistic | Corn | Live Cattle | Lean Hogs | Exchange Rate |
|---|---|---|---|---|
| Mean | 344.72 | 90.76 | 65.14 | 90.77 |
| Maximum | 806.50 | 168.87 | 132.65 | 120.59 |
| Minimum | 180.25 | 57.35 | 28.55 | 72.16 |
| Std. Dev | 153.46 | 26.26 | 17.42 | 11.08 |
| Skewness | 1.26 | 1.01 | 0.72 | 0.69 |
| Kurtosis | 3.73 | 3.13 | 3.78 | 2.90 |
| Jarque-Bera | 83.69 | 50.17 | 32.73 | 22.97 |

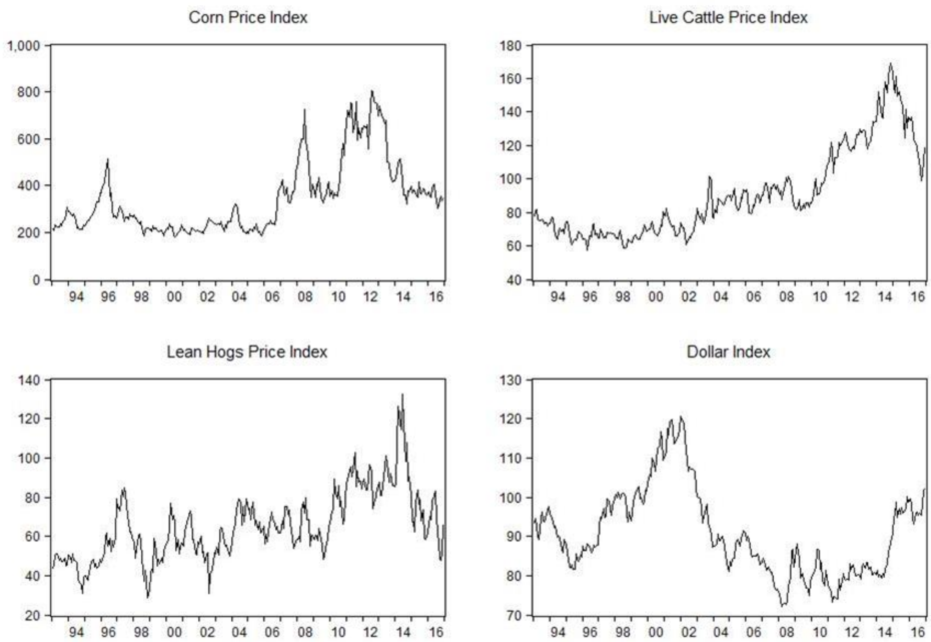


**Figure 1. Monthly Price Series of the Agricultural Commodities, and Exchange Rate**

Application of the Granger causality test requires that all time series data are stationary; otherwise the inference might be spurious because the test statistics will have nonstandard distributions. Researchers over the years have proposed numerous methods for testing stationarity and the Augmented Dickey-Fuller (ADF) test developed by Dickey and Fuller (1979, 1981) is one of the most widely used measures in econometric literature. ADF tests the null hypothesis that the series are non-stationary (i.e., presence of a unit root), and the alternative hypothesis that they are stationary (i.e., absence of a unit root). Table 2 shows the results of the Augmented Dickey Fuller (ADF) tests for unit roots of the variables for both the levels and first differences. The results indicate that the null hypothesis of unit root is not rejected for the levels indicating the presence of non-stationarity in the data series. However, the ADF tests on the differenced variables show that the data series is stationary. The results show that all the variables in the data are integrated and of the same order, I(1). Hence we proceed for formal tests for cointegration to see whether any combinations of the variables are cointegrated.

**Table 2. Augmented Dickey Fuller (ADF) Test Results**

| Variables | Test Results for Variables in Levels | p-values for Variables in Levels | Test Results after First Differencing |
|---|---|---|---|
| Corn | -2.56 | 0.29 | -17.49* |
| Live Cattle | -3.10 | 0.11 | -10.82* |
| Lean Hogs | -2.37 | 0.15 | -18.03* |
| FX Rate | -1.92 | 0.63 | -11.44* |

**Note:** * indicate significance at 1% level

Johansen's cointegration test was applied to examine whether the selected variables share the same stochastic trend and consequently whether a stable long-run linkage exists between them. The Johansen's test reports two tests for cointegration: trace test (designed to test the presence of *r* cointegrating vectors) and max-eigen value test (designed to test the hypothesis of *r* cointegrating vectors in *r+1* cointegrating vectors). Table 3 shows the results of trace test statistic, 5% critical value and the corresponding p-value. The test results show that there is no cointegration among the study variables as indicated by the high p-values. The cointegration results reveal that only short run dynamic interactions exist and there is no stable, long run equilibrium relationship among corn, live cattle, lean hogs and exchange rates.

**Table 3. Johansen Cointegration Test Results**

| $H_0$: Rank = $r$ | Trace Statistic | 5% Critical Value | Probability |
|---|---|---|---|
| $r = 0$ | 55.11 | 63.87 | 0.21 |
| $r \leq 1$ | 27.05 | 42.92 | 0.67 |
| $r \leq 2$ | 12.27 | 25.87 | 0.79 |
| $r \leq 3$ | 4.15 | 12.51 | 0.71 |

**Note**: *r* represents the number of linearly independent cointegrating vectors. *Trace test indicates no cointegration at the 5% level

The Johansen's cointegration test results as reported in Table 3 imply that short run dynamics exist between grain, meat prices and exchange rates. Hence, the commodity prices could be better modeled through the vector auto regression (VAR) system than the vector error correction model (VECM). The VAR model is estimated by using the same lag length (lag=2) which was employed in the previous cointegration test. Table 4 shows the results of the VAR model estimates. Form the table, it is evident that all the commodities (corn, live cattle, lean hogs) and exchange rates are positively related to their own lags. The only exception is the exchange rate which is positively related to its first lag, but is negatively related to the second lag. The results also show that corn is related to the first and second lags of lean hogs and live cattle are related to the second lag of lean hogs.

Pairwise Granger causality tests are conducted to understand the causal relations among the variables and the results are summarized in Table 5. A unidirectional causal influence from corn prices to lean hogs is observed at 5% level of significance. The results show that live cattle prices granger cause corn and lean hogs prices. F-statistics show that the null hypothesis of lean hogs prices do not granger cause corn is rejected at 1% significance level. This result is confirmed by previous VAR results in Table 4, where past values of lean hogs influence current values of corn. Furthermore, changes in exchange rates influence corn and lean hogs prices. While the majority of the price relationships reported here are unidirectional, the results suggest a bidirectional relationship between corn and lean hogs prices. The reported F-statistics and p-values suggest that live cattle and exchange rate markets do not have any causal relationship.

**Table 4. Vector Auto Regression (VAR) Parameter Estimates**

| | Corn | Live Cattle | Lean Hogs | FX Rate |
|---|---|---|---|---|
| Constant | 81.018* (38.63) | 5.842 (4.33) | 1.447 (6.41) | 2.095 (1.41) |
| $Corn_{t-1}$ | 0.873* (0.06) | -0.001 (0.006) | 0.004 (0.01) | -0.002 (0.002) |
| $Corn_{t-2}$ | 0.057 (0.06) | 0.004 (0.006) | -0.002 (0.01) | 0.002 (0.002) |
| Live $Cattle_{t-1}$ | 0.785 (0.56) | 1.006* (0.06) | 0.139 (0.09) | 0.011 (0.02) |
| Live $Cattle_{t-2}$ | -0.513 (0.58) | -0.075 (0.06) | -0.017 (0.09) | -0.032 (0.02) |
| Lean $Hogs_{t-1}$ | 1.288* (0.38) | -0.063 (0.043) | 0.774* (0.06) | 0.012 (0.01) |
| Lean $Hogs_{t-2}$ | -1.603* (0.38) | 0.097* (0.04) | 0.043 (0.06) | 0.007 (0.01) |
| FX $Rate_{t-1}$ | 0.991 (1.65) | -0.157 (0.18) | 0.399 (0.27) | 1.281* (0.06) |
| FX $Rate_{t-2}$ | -1.679 (1.66) | 0.118 (0.18) | -0.403 (0.27) | -0.303* (0.06) |

**Note:** *denote significance at 5% significance level. Values in parenthesis below parameter estimates indicate standard errors.

**Table 5. Pairwise Granger Causality Test Results**

| Null Hypothesis | F-Statistics | p-value |
|---|---|---|
| Corn $\not\Rightarrow$ LC | 1.14 | 0.33 |
| Corn $\not\Rightarrow$ LH | 2.39** | 0.05 |
| Corn $\not\Rightarrow$ FX | 0.50 | 0.72 |
| LC $\not\Rightarrow$ Corn | 4.87*** | 0.00 |
| LC $\not\Rightarrow$ LH | 6.62*** | 4.0E-05 |
| LC $\not\Rightarrow$ FX | 0.60 | 0.66 |
| LH $\not\Rightarrow$ Corn | 6.68*** | 4.0E-05 |
| LH $\not\Rightarrow$ LC | 1.46 | 0.21 |
| LH $\not\Rightarrow$ FX | 1.49 | 0.20 |
| FX $\not\Rightarrow$ Corn | 2.23* | 0.06 |
| FX $\not\Rightarrow$ LC | 1.68 | 0.15 |
| FX $\not\Rightarrow$ LH | 2.79** | 0.02 |

**Notes:** $\not\Rightarrow$ implies "does not granger cause" X $\not\Rightarrow$ Y means variable X does not Granger cause Y. *** denote 1% significance level, ** 5% significance level, * 10% significance level.

In order to analyze the magnitude of the response of shock on the grain, meat prices and exchange rates, a 24 period impulse response function analysis is conducted and their results are presented in Figure 2. The impulse response function shows how a shock to one variable affects itself and the other variables in the VAR system over time while holding all other external effects constant. The responses of corn to unexpected orthogonal shocks to the other variables are given in the first row of the Figure 2. From the figure, it is evident that corn reacts positively to unexpected shocks to lean hogs and exchange rate. This initial reaction is short lived and lasts only up to 5 months. The responses of live cattle to the orthogonal shocks are given in the second row of the figure. Live cattle responds positively to an unexpected shock to corn and lean hogs; and responds negatively to shocks to exchange rate. Lean hogs respond positively to shocks to corn. Finally, the fourth row gives the responses of exchange rate to the orthogonal shocks. Exchange rate reacts negatively to a shock to both corn and live cattle. However, the negative shock effect is short lived for corn.

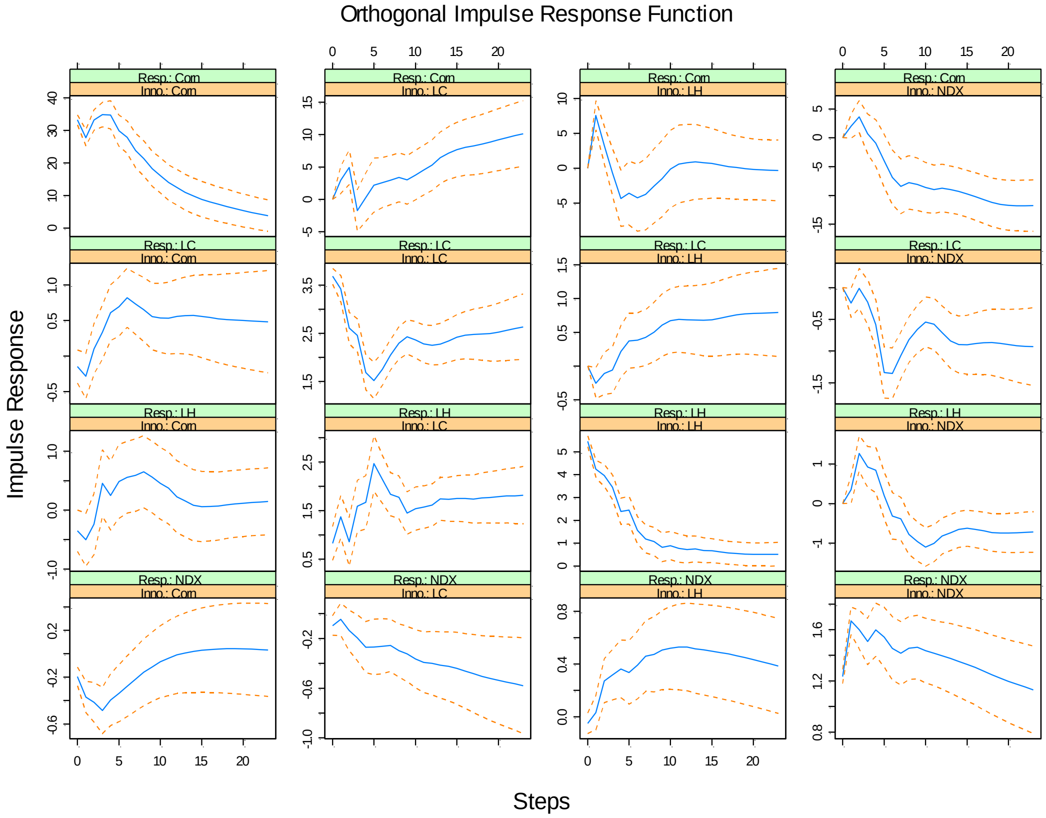


**Figure 2. Orthogonal Impulse Response Function Results**

## 5. Conclusion

The purpose of the present paper is to investigate whether grain, meat prices and exchange rates are interrelated by employing a series of econometric tests. The results of the Granger causality tests show that a bidirectional relationship exists between corn and lean hog prices. Unidirectional causality was found from live cattle prices to corn and lean hog prices. When the Johansen approach is considered for the presence of long-run interrelationships, empirical results showed that there is no cointegration among study variables and consequently confirmed the existence of only short run dynamics between grain and meat prices and exchange rates. The impulse response functions based on VAR models confirm that the agricultural commodity prices respond to shocks originating from other markets.

Fluctuations in grain prices like corn which typically used as an input in livestock production would influence the meat prices as well. Changes in the prices of agricultural products like meats and grains, and fluctuations in quantities exported or imported through the strength or weakness of the U.S. dollar will affect the farm income and ultimately the well-being of the farming community. Understanding these inter commodity price linkages will help farmers in properly designing their hedging programs, adjusting the marketing strategies based on prevailing market conditions thereby improving returns while minimizing risk. Market investors could also benefit from studying price linkages, as it helps them better understand how shocks in one market could affect other markets.

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