# RELATIONSHIPS AMONG PRICES ACROSS
# ALTERNATIVE MARKETING
# ARRANGEMENTS FOR FED
# CATTLE AND HOGS

By

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# CHAPTER I

# INTRODUCTION

## Background

Impacts of captive supplies have been studied over the past couple decades mostly for fed cattle. Captive supplies refer to livestock that are committed to a specific buyer two weeks or more before slaughter (Ward 2007). There are three types of captive supply methods commonly used by packers; marketing and purchasing agreements, forward contracts, and packer ownership of livestock. In the traditional procurement method, known as a cash (spot) market purchase, buyers observe cattle at the feed yard and purchase cattle for lot-specific price bids, based on a live-weight basis. Cattle purchased by the traditional methods are usually shipped to buyers within about 1 week of purchase (Schroeter and Azzam 2003).

The term captive supplies has more recently been replaced by alternative marketing arrangements (AMAs) since the mandatory price reporting system began in 2001 (Ward 2008). The Agricultural Marketing Service (AMS) categorizes marketing and purchasing methods differently. For fed cattle, AMAs include negotiated purchases, negotiated grid purchases, formula marketing arrangements, forward contracts, and packer owned transfers. For slaughter hogs, AMAs include negotiated purchases, swine market formula purchases, other market formula purchases, other purchase arrangements, and packer-owned transfers.

The use of AMAs for the beef and pork industries has increased. Especially, in the pork industry, the reliance on AMAs is high. Hog producers, cattle feeders and meat packers gain benefits from the use of AMAs. For producers and cattle feeders, benefits include improved price risk management, improved access to financing, a guaranteed buyer, increased quality premiums, improved information, and reduced marketing costs. For meat packers with captive supplies, important benefits include securing slaughter needs for their plants, having more control over the type and quality of cattle and hogs, and reducing procurement costs (Muth. et. al. 2005).

The increased use of AMAs in the beef and pork industries generates many concerns about effects of market efficiencies, preferential pricing between meatpacking firms and livestock suppliers, and the contribution to profits. One reason that the increased use of AMAs between packers and feedlots has raised concerns is the incomplete information about prices. Accurate information on prices for individual AMA transactions plays an important role in improving market efficiency and increasing transparency in the market. In previous studies before mandatory price reporting, researchers conducted their studies about captive supplies with data collected by the voluntary price reporting system. Results from those previous studies led to questions about the effectiveness of voluntary price reporting.

In 2001, Mandatory Price Reporting (MPR) was implemented in part to increase information available on captive supplies. According to studies relative to the effects of

MPR, the mandatory price reporting system created several new data series regarding volume and prices for purchases of livestock by packers under AMAs, and increased transparency regarding use of AMAs (Ward 2008). These new, accessible data imply impacts of AMAs could be more clearly analyzed in economic and statistical aspects. In addition, precise information between price series will aid producers and buyers make choices regarding marketing methods, as well as policy makers to decide whether use of AMAs has positive or negative effects on livestock and meat industries. As a part of the economic effects of AMAs, this research will analyze how price series across AMAs for fed cattle and hogs are related, and how each price affects each other.

## Objective

The general objective of this paper examines hypotheses regarding the relationship between the negotiated cash price and each individual alternative marketing arrangement (AMA) using cointegration and causality tests. The specific objectives are 1) to estimate whether or not the linear combinations of prices for AMAs include an equilibrium relationship ( price are cointegrated), and if the prices are cointegrated, how many cointegrating ranks exist between negotiated cash market prices and individual prices of AMAs for fed cattle and hogs; 2) to analyze the sign of the relationship between the cash market price and other procurement prices based on the existence of cointegration; 3) to determine the extent of the speed that prices for AMAs move back to their equilibrium if prices for AMAs are cointegrated; and 4) to estimate the direction toward which prices for AMAs affect other prices based on a vector error correction model.

This paper reports on Johansen's cointegration tests to determine whether there exists an equilibrium relationship in the long run between negotiated cash market prices and individual AMA prices. In addition, if it is determined that prices for fed cattle and hogs are cointegrated, this paper reports on estimates of the existence of cointegrating vectors. To confirm results from Johansen's cointegration tests, the Stock-Watson test is estimated. Based on the existence of the cointegration in price series for fed cattle and hogs, this paper determines relationships between the cash market prices and other procurements prices when the market enters the long run, as well as the role of cash market prices in price discovery.

# CHAPTER II

# LITERATURE REVIEW

Previous studies have analyzed the effects of using different types of marketing arrangements on transaction prices for fed cattle, but, in most cases, studies focused on the impacts of captive supplies on cash market prices rather than the direct relationship between price series of captive supplies.

Ward, Koontz, and Schroeder (1998) estimated impacts of captive supplies on transaction prices for fed cattle based on an inventory of captive supplies. The authors found captive supplies negatively affect transaction prices, but the effects are small.

Capps et al. (1999) estimated characteristics related to the choices of fed cattle procurement and pricing methods with daily data collected from April 1992 to April 1993 by a using multinomial logit model. The methods of procurement and pricing are affected by several market condition variables and information about the beef industry.

Schroeter and Azzam (2004) estimated the relationship at the plant level between cash market prices and captive supplies for fed cattle. When plants have high degrees of reliance on captive supplies, the plants are a concern to their regional market rivals and the plants pay below average prices in the spot market. Increasing use of captive supplies induces negative impacts on spot market prices.

Hunnicutt, Bailey, and Crook (2004) estimated relationships between feedlots and packers in the fed cattle case. They found that feedlots are preferentially and stably connected to packers. These relationships implicitly imply there could be stable relationships among the prices for AMAs.

Koontz and Ward (2008) estimated the impacts of the mandatory price reporting. They found that mandatory price reporting helped analysts and industry users of mandatory price reports access data not previously available about price discovery. They also suggested mandatory price reporting increased transparency and price information.

Pendell and Schroeder (2006) attempted to address price discovery efficiency and overall market performance across fed cattle regions and the effects of implementing a mandatory price reporting system under data collected by mandatory price reporting (MPR). The authors empirically tested how mandatory price reporting has influenced spatial market integration among five major U.S regional fed cattle markets. To identify long-run price relationships among five major U.S regional fed cattle markets, The authors used cointegration testing procedure. The distinguishable point of this paper was the application of new weekly data since implementing MPR. This study used bivariate and multivariate time-series models in order to examine spatial market integration relationships. First, nonstationarity of each individual price series was tested, and then the Augmented Dickey-Fuller (ADF) unit root test was used to test stationarity of estimated residuals by using Ordinary Least Squares (OLS) to determine whether variables are cointegrated or not. The next step was to estimate the number of cointegrating vectors by the Johansen approach. The fact there were cointegrating vectors implies that the economic system is stable. Also, this paper estimated the possible structural changes in fed cattle price relationships by allowing for structural change in the intercept and the slope vector. They found there existed a long-run relationship among all five regional fed cattle markets from results of the Engle-Granger approach for bivariate models and Johansen's cointegration test for multivariate models. These cointegrated regional market prices did not tend to diverge from one another in the long run. Also, markets were cointegrated regardless whether or not they allowed for a structural change in the relationship at the beginning of MPR.  Authors found that after the implementation of MPR, the five regional fed cattle markets became more integrated, and concluded that MPR increased the content of price information and the level of trust in the information by users compared with prior to MPR.

Muth et al. (2008) estimated fed cattle price and price risk differences across AMAs with using data collected from October 2002 to March 2005 by 29 large beef packing plants. The authors concluded AMAs was the best contract methods between price level and price risk. Also they found that forward contracts had the lowest average prices among AMAs, but prices were more volatile than others.

The study of preferential pricing between meatpacking firms and livestock suppliers in fed cattle and hogs was conducted by Ward (2008). This research examined the behavior of weekly AMA prices for the first seven years of mandatory price reporting, both for fed cattle and hogs. The author used weekly data which were collected in part by the Livestock Marketing Information Center and Texas Cattle Feeder Association, as well as the author. The author used largely graphical analysis in this paper. For fed cattle, prices by AMAs tracked cash market prices closely with the exception of forward contracts. In hogs, swine market formula arrangements tracked cash market prices very closely, though other formula arrangements and other procurement method prices did not. This study concluded that both for fed cattle and hogs, arrangements that include some sort of price risk management element did not track cash market prices as well as those that simply facilitated price discovery tied to the cash market. Also, no procurement method consistently paid higher or lower prices than another. Finally, cash market prices lead AMA prices in upward trending markets and trailed AMA prices in downward trending markets.

Previous studies imply that researchers need to directly investigate the relationship between prices in the spot market and AMAs. This paper will approach how prices across AMAs are linked to each other by using different methods. The empirical model underlying this study will be built on the existing theoretical literature (Pendell and Schroeder 2006).

# CHAPTER III

## CONCEPTUAL FRAMEWORK

Many macroeconomic time series tend to be nonstationary in their levels. In order to analyze relationships among nonstationary time series, the cointegration test is useful. Many researchers have used the Engle and Granger (1987) procedure in testing for cointegration, but this procedure has some flaws (Pendell and Schroeder 2006). Suppose price series are more than two and only one cointegrating vector exists. However, there can be more than one cointegrating vector in multivariate models. These problems cannot be solved by the Engle and Granger approach. To treat these deficiencies, Johansen (1988), and Stock and Watson (1988) have suggested alternative tests for cointegration and methods for estimating the cointegrating vectors (Dickey et. al 1991).

Ward (2008) estimated the existence of preferential pricing by packers with new weekly data. The author found according to the graphical analysis that negotiated grid prices and formula prices for fed cattle closely track negotiated cash market prices but the forward contract prices were slightly different from others. In the hog case, other formula prices and other purchase prices except for the swine market formula prices did not track the cash market prices closely. Figures 2 and 3 show those results. Why does it appear some track more closely than others?

Each AMA price for fed cattle and hogs is based on a different pricing process. In fed cattle case, the negotiated cash market price is based on the cash market price discovered by negotiation between buyer and seller. The formula price is based on the base price for a grid tied to a quoted cash market price, such as the five-state weighted average price or top-of-the-market price or tied to the plant average price for the slaughter plant. The forward contract price is based on the basis contracts with the price tied to basis (cash market price minus closing nearby futures contract price).

In the hog case, the negotiated cash market price is based on the cash market price determined by negotiation between buyer and seller. The swine market formula price is based on the base price for carcass merit tied to a quoted cash market price, like a formula price for fed cattle. An other formula price is a price tied to the closing nearby futures contract price. An other purchase price is based on the price which is discovered by a formula which might be tied to cost of production or window contracts. These results implicitly imply some prices for AMAs would be cointegrated in both cases for fed cattle and hogs.

Also, Ward (2008) found cash market prices lead prices for AMAs only on rising markets. Last week's cash market price mainly affects this week's price. This indicates that the information from the last week's cash market price is a key element in price discovery. Thus, one would expect cash market prices would largely affect individual AMA prices by estimating the direction of causality between the negotiated cash prices and each price for AMAs.

In this paper, the Johansen, and Stock and Watson approaches to cointegration will provide a framework to analyze long-run price relationships among AMA prices for fed cattle and hogs. Conceptually, the results from the Granger causality test will provide us with insight into the efficiency of price discovery in the fed cattle and hog markets.

## Data

Data were compiled from multiple Agricultural Marketing Service (AMS), USDA, Mandatory Price Reports. By number, reports include: fed cattle-LM_CT150, LM_CT151, LM_CT153, LM_CT163, LM_CT164, LM_CT165, LM_CT166, and LM_CT167; hogs- LM_HG200. All data can be accessed at http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=templateA&navID=MarketNewsAndTransportationData&leftNav=MarketNewsAndTransportationData&page=MarketNewsAndTransportationData&acct=AMSPW .

Data were collected in part by the Livestock Marketing Information Center and Texas Cattle Feeders Association, as well as Ward and his associates. Data used in this paper are the same as data used by Ward (2008).

Weekly time series price data for fed cattle and hogs were collected from May 2001 to May 2008. In the negotiated grid price data for fed cattle, missing observations numbered 151 because the negotiated grid price was only continuously reported since April 2004. In the forward contract price data series for fed cattle, missing observations were 13. Summary statistics of the weekly price series for both fed cattle and hogs in levels and first differences are presented in table 1.

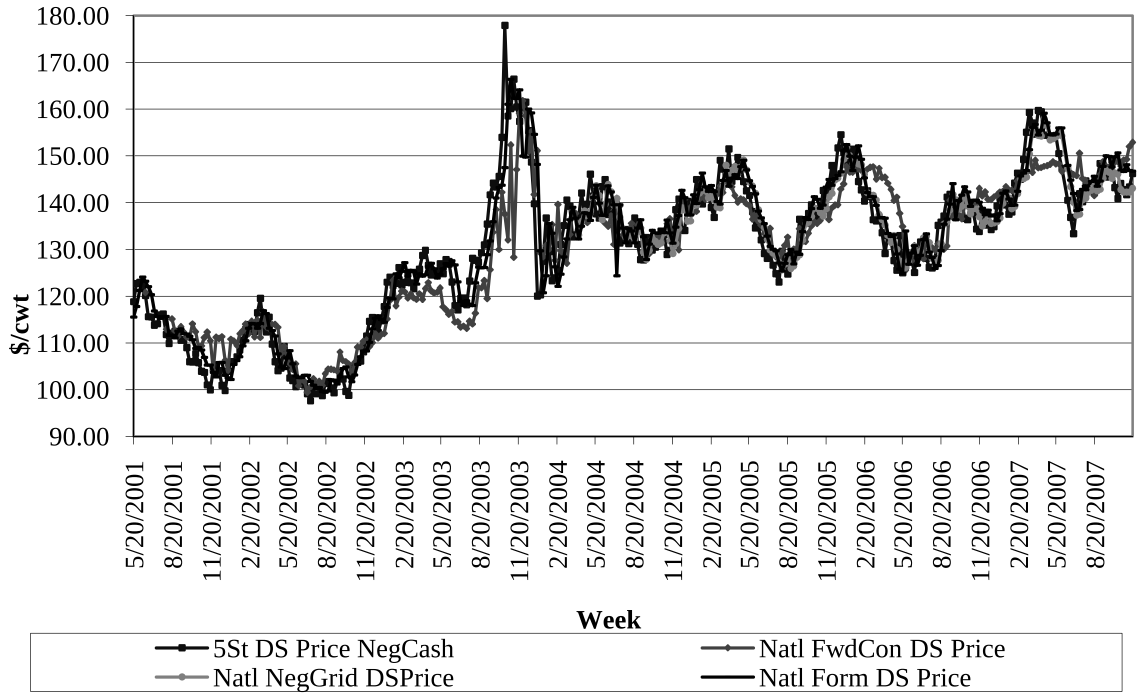


**Figure III-1. Negotiated Cash Price vs. Other Procurement Methods for Fed Cattle**

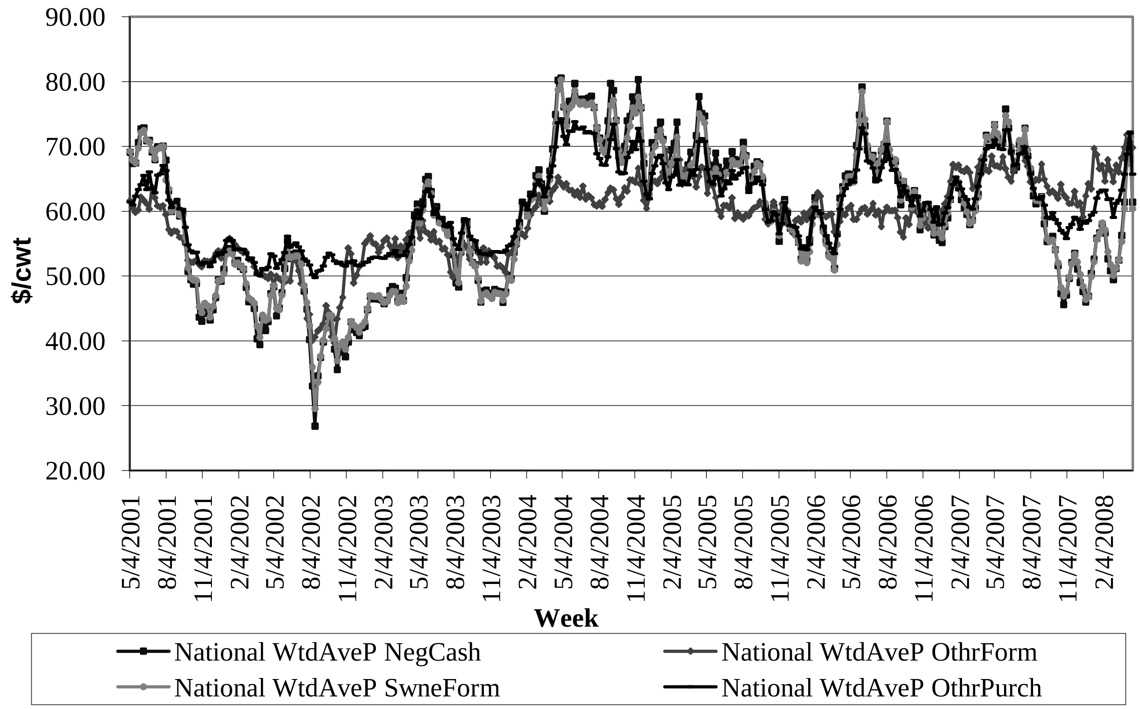


**Figure III-2. Negotiate Cash Price vs. Other Procurement Methods for Hogs**

**Table III-1. Summary Statistics for Fed Cattle and Hogs Procurement Prices, May 2001- May 2008**

| Procurement method | N | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| Fed cattle | | | | | |
| Levels ($/dressed cwt) | | | | | |
| Negotiated cash price | 364 | 131.16 | 15.90 | 97.90 | 177.97 |
| Forward contract price | 351 | 132.01 | 15.34 | 15.34 | 161.82 |
| Negotiated grid price | 213 | 139.79 | 7.14 | 7.14 | 157.95 |
| Formula price | 364 | 131.72 | 15.72 | 15.61 | 166.39 |
| | | | | | |
| First difference | | | | | |
| dNegotiated cash price | 363 | 0.08 | 3.74 | -19.75 | 23.96 |
| dForward contract price | 350 | 0.11 | 3.79 | -24.04 | 20.33 |
| dNegotiated grid price | 212 | 0.07 | 2.16 | -6.94 | 4.88 |
| dFormula price | 363 | 0.09 | 3.22 | -18.48 | 15.20 |
| | | | | | |
| Hogs | | | | | |
| Levels ($/live cwt) | | | | | |
| Negotiated cash price | 364 | 59.35 | 10.75 | 28.88 | 80.59 |
| Other formula price | 364 | 58.91 | 6.10 | 39.70 | 71.80 |
| Swine formula price | 364 | 59.17 | 10.34 | 29.56 | 80.28 |
| Other purchase price | 364 | 60.81 | 6.27 | 49.79 | 74.28 |
| | | | | | |
| First difference | | | | | |
| dNegotiated cash price | 363 | -0.02 | 2.79 | -10.50 | 7.77 |
| dOther formula price | 363 | 0.02 | 1.54 | -4.50 | 6.21 |
| dSwine formula price | 363 | -0.02 | 2.47 | -11.29 | 6.93 |
| dOther purchase price | 363 | 0.01 | 1.61 | -6.29 | 4.30 |

## Methods

Figure 3 shows the step by step procedure followed. First, stationarity tests (unit root) of individual prices series across AMAs for fed cattle and hogs were conducted using the Augmented Dickey-Fuller (ADF) test. If individual price series across AMAs are nonstationary (have a unit root), then one can perform cointegration tests. On the other hand, when individual price series are stationary (have no unit root), a vector autoregressive (VAR) model in levels is appropriate.

Second, cointegration tests based on the ADF test determine whether there exists a long-run relationship among the AMA price series in bivariate and multivariate models. If prices are integrated of the same order but prices of each model are not cointegrated, VAR model in first differences is appropriate. If prices are integrated of the same order and prices of each model are cointegrated, a vector error correction model (VECM) is appropriate to determine the multivariate relationships among prices. Finally, based on the vector error correction model, causality tests are conducted to estimate how one price affects another price between pairs of AMAs.

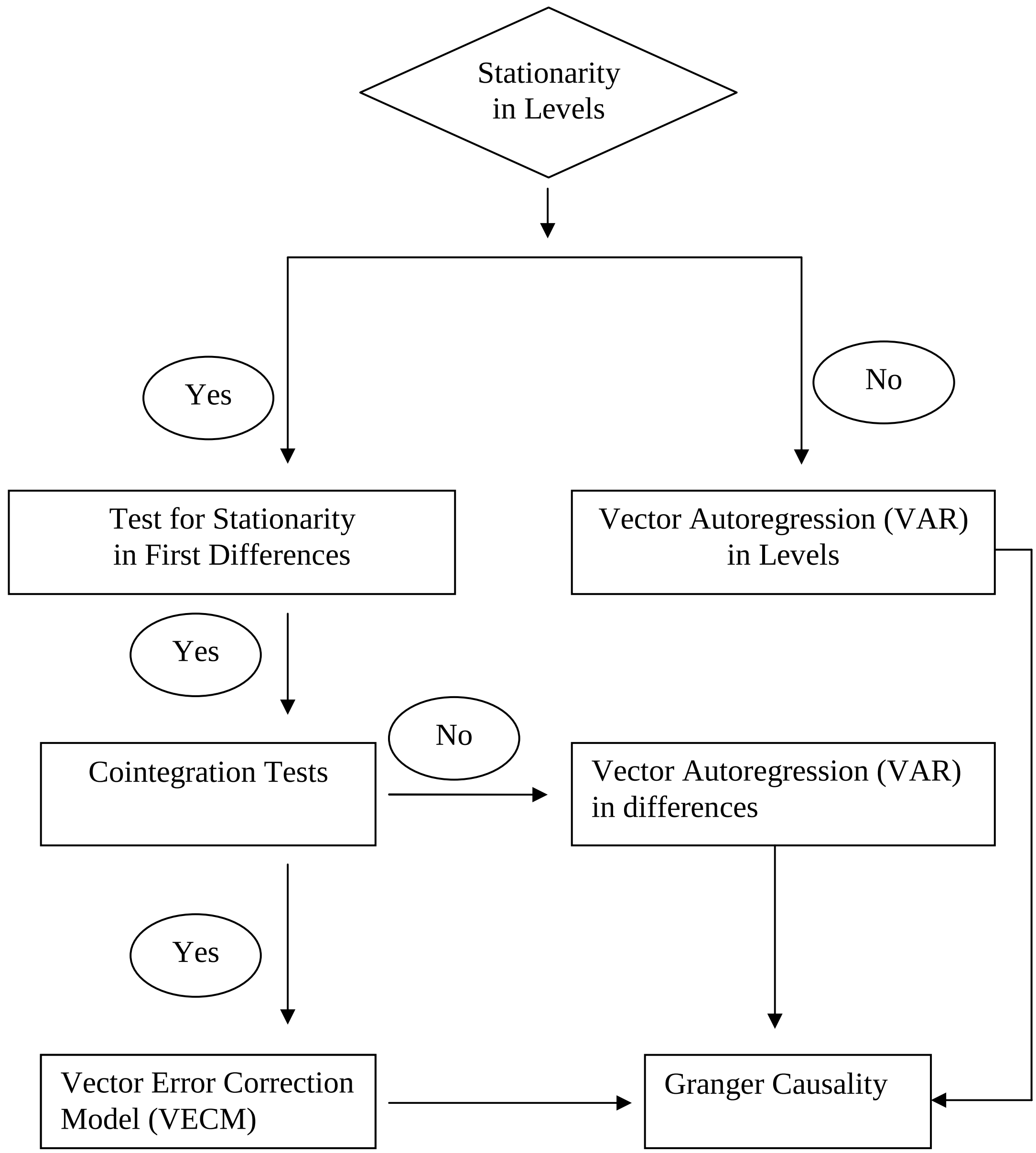


**Figure III-3. Schematic Design of Time Series Model Selection Procedure**

# CHAPTER IV

# ESTIMATIONS AND RESULTS

## Stationarity Tests

The stationarity of a time series can be tested with the Dickey-Fuller test. Consider the AR (1) model for the time series variable $x_t$ :

$$x_t = \rho x_{t-1} + \nu_t. \quad (1.1)$$

Assume that $\nu_t$ is a random disturbance with zero mean and constant variance ${\sigma_\nu}^2$. In this model, if $\rho = 1$ then $x_t$ is the nonstationary random walk, $x_t = x_{t-1} + \nu_t$, which means the model has a unit root. If $|\rho| < 1$ then the model (1.1) is stationary. Therefore one can test the null hypothesis that $\rho = 1$ against the alternative that $|\rho| < 1$. To obtain the differenced model by subtracting $x_{t-1}$ from both sides of (1.1):

$$x_t - x_{t-1} = \rho x_{t-1} - x_{t-1} + \nu_t,$$

$\Delta x_{t-1} = (\rho - 1)x_{t-1} + \nu_t$, and

$$\Delta x_{t-1} = \gamma x_{t-1} + \nu_t, \quad (1.2)$$

where $\gamma = (\rho - 1)$.

Then the null hypothesis is that $\gamma = 0$, and the alternative hypothesis is that $\gamma < 0$.

There are three regression equations that can be used to test for the existence of a unit root;

$$\Delta x_{t-1} = \gamma x_{t-1} + \nu_t \quad \text{(No intercept)}, \tag{1.3}$$

$$\Delta x_{t-1} = a_0 + \gamma x_{t-1} + \nu_t \quad \text{(Intercept but no time trend)}, \tag{1.4}$$

$$\Delta x_{t-1} = a_0 + \gamma x_{t-1} + a_2 \mathrm{t} + \nu_t \quad \text{(Intercept and time trend)}. \tag{1.5}$$

The difference among the three regression equations are the deterministic elements $a_0$ and $a_2$. The first equation (1.3) is a pure random walk model, the second equation (1.4) includes an intercept or random walk with drift, and the third equation (1.5) includes a drift and time trend. The critical values for $\gamma = 0$ depend on whether equations include an intercept or time trend, as well as sample size. The statistics for three different equations are $\tau$, $\tau_\mu$,and $\tau_\tau$, respectively.

However, all time series processes cannot be represented by the first-order autoregressive process. It is possible to use an *n*th-order autoregressive process:

$$x_t = a_0 + a_1 x_{t-1} + a_2 x_{t-2} + a_3 x_{t-3} + \cdots + a_{p-1} x_{t-p+1} + a_p x_{t-p} + \nu_t, \tag{1.6}$$

Add and subtract $a_p x_{t-p+1}$ from (1.6):

$$x_t = a_0 + a_1 x_{t-1} + a_2 x_{t-2} + a_3 x_{t-3} + \cdots + (a_{p-1} + a_p) x_{t-p+1} - a_p \Delta x_{t-p} + \nu_t \tag{1.7}$$

Again, add and subtract $(a_{p-1} + a_p) x_{t-p+2}$ from (1.7):

$$x_t = a_0 + a_1 x_{t-1} + a_2 x_{t-2} + \cdots + (a_{p-1} + a_p) \Delta x_{t-p+2} - a_p \Delta x_{t-p+1} + \nu_t, \tag{1.8}$$

Therefore, this results in

$$\Delta \mathit{\Delta} x_t = a_0 + \gamma x_{t-1} + \sum_{i=1}^{n} \beta_i \mathit{\Delta} x_{t-i} + \nu_{t-i}, \tag{1.9}$$

where $\gamma = -(\sum_{i=1}^{n} a_i)$, and $\beta_i = \sum_{j=i}^{n} a_j$ .

In the extended Dickey-Fuller test, called an Augmented Dickey-Fuller (ADF) test, the coefficient of interest is $\gamma$. If $\gamma = 0$ (or $\sum_{i=1}^{n} \alpha_i = 0$), the equation has a unit root.

Also, we determine the order of integration of each price series by the ADF test. The ADF test uses the same three statistics as the DF test mentioned above.

This paper applies the equation (1.4) that includes an intercept but no time trend. There is a question concerning whether it is most appropriate to estimate the equations (1.3), (1.4) or (1.5). Data used in this paper do not include time trends and thus, the equation (1.4) is appropriate. The lag length is determined by the Akaike Information Criterion (AIC).

Tables 2 and 3 report the augmented Dickey-Fuller (ADF) tests for fed cattle and hogs estimated in levels and first differences, respectively.

**Table IV-1. Augmented Dickey-Fuller (ADF) Results for Fed Cattle with Weekly Data, May 2001-May 2008**

| Procurement methods | Test results in levels | Test results after first-differencing |
|---|---|---|
| Negotiated cash price | -1.92(3) | -11.43**(2) |
| Forward contract price | -1.45(2) | -16.40**(1) |
| Negotiated grid price | -3.09(5)** | -5.51**(4) |
| Formula trade price | -1.80(3) | -11.53**(2) |

Notes: Double (**) indicate the rejection of the null hypothesis that there is a unit root at the 5% significance level. The critical value at the 5% is -2.86. The numbers inside parenthesis ( ) are the chosen lag length. Each equation included an intercept but no time a trend is estimated by ADF test.

**Table IV-2. Augmented Dickey-Fuller (ADF) Results for Hogs with Weekly Data, May 2001-May 2008**

| Procurement methods | Test results in levels | Test results after first-differencing |
|---|---|---|
| Negotiated cash | -2.69(3) | -12.03**(2) |
| Other formula | -1.79(1) | -21.30**(0) |
| Swine formula | -2.66(3) | -11.54**(2) |
| Other purchase | -3.07(3)** | -14.98**(0) |

Notes: Double (**) indicate the rejection of the null hypothesis that there is a unit root at the 5% significance level. The critical value at the 5% is -2.86. The numbers inside parenthesis ( ) are the chosen lag length. Each equation included an intercept but no time a trend is estimated by ADF test.

***Fed cattle*** - The middle column of table 2 indicates the negotiated cash, forward contract price, and formula prices fail to reject the null hypothesis that prices are nonstationary (have a unit root) at the 5% significance level. However, negotiated grid prices reject the null hypothesis at the 5% significance level which means the negotiated grid price is stationary (no unit root) at the 5% significance level.

***Hogs*** **–** The results fail to reject the null hypothesis that each individual price series is nonstationary (has a unit root) at the 5% significance level but not other purchase prices. The middle column of table 3 shows that the price series except for other purchase prices are nonstationary at the 5% significance level. Other purchase prices reject the null hypothesis of nonstationarity at the 5% significance level. That is, other purchase prices are stationary (no unit root) at the 5% significance level.

To make each price for fed cattle and hogs stationary, they need to be transformed. The last column of tables 2 and 3 shows that after first differencing each price series, all prices for fed cattle and hogs are stationary at the 5% significance level. Thus, it is concluded that after first differencing each of the hog price series, all are integrated of order one, [$I$ (1)]. Both for fed cattle and hogs, if all prices in levels are nonstationary at the 5% and 1% significance level, respectively and all prices in first differences are stationary at the 5% significance level then one can conduct cointegration tests.

## Johansen's Cointegration Tests

Based on the augmented Dickey-Fuller (ADF) test, cointegration tests for fed cattle and hogs are possible because prices for hogs are integrated of order 1, [$I$ (1)], and are conducted by Johansen's approach in bivariate and multivariate models.

David et al. (1991) stated that cointegration means one or more linear combinations of nonstationary economic variables are stationary. If those nonstationary variables are cointegrated, they cannot move too far away from each other. On the contrary, the lack of cointegration among a set of integrated variables implies no long-run equilibrium among the variables, so that they can wander arbitrarily far from each other.

To perform cointegration tests, one should consider four important points noted by Enders (2003). First, cointegration refers to one or more linear combinations of nonstationary variables. Second, all variables must be integrated of the same order. However, this condition is not necessarily required in all cases. It is possible that variables are integrated of different orders. Third, there may be as many as $n$-1 linearly independent cointegrating vectors if a linear combination of nonstationary variables has $n$ variables. The number of cointegrating vectors is called the cointegrating rank ($r$). If more than two time series are considered, it is possible to have more than one cointegrating rank. Finally, consider the case in which each variable contains a single unit root. Before conducting the cointegration tests, the lag lengths are determined by using the minimum value of the Akaike information criterion.

In order to conduct Johansen's cointegration test, a vector error correction model (VECM) was used. Assume $y_t$and $x_t$ are price series; then using matrix notation where $z_t$ =$(y_t, x_t)'$:

$$z_t = A_1 z_{t-1} + A_2 z_{t-2} + \cdots + A_k z_{t-k} + u_t. \tag{1.10}$$

Equation (1.10) is reformulated as a VECM as follows:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \Gamma_2 \Delta z_{t-2} + \cdots + \Gamma_{k-1} \Delta z_{t-k-1} + \Pi z_{t-1} + u_t, \tag{1.11}$$

where $\Gamma_i = (I - A_1 - A_2 - \cdots - A_k)$ (I=1,2,…, K-1) and $\Pi = -(I - A_1 - A_2 - \cdots - A_k)$. One needs to examine the 2×2 matrixes, Π, because each bivariate model has two variables in $z_t$ = $[y_t, x_t]$. The Π matrix contains information regarding the long-run relationships. Matrix, Π, is decomposed by αβ' where α will include the speed of adjustment at which each variable moves back to its long-run equilibrium while β' will contain the cointegrating vectors that represent the underlying long-run relationship. For simplicity this paper assumes that k=2. The model is then the following;

$$\begin{pmatrix} \Delta y_t \\ \Delta x_t \end{pmatrix} = \Gamma_1 \begin{pmatrix} \Delta y_{t-1} \\ \Delta x_{t-1} \end{pmatrix} + \Pi \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} + e_t, \tag{1.12}$$

or

$$\begin{pmatrix} \Delta y_t \\ \Delta x_t \end{pmatrix} = \Gamma_1 \begin{pmatrix} \Delta y_{t-1} \\ \Delta x_{t-1} \end{pmatrix} + \begin{pmatrix} \alpha_{11} \\ \alpha_{21} \end{pmatrix} (\beta_{11} \quad \beta_{12}) \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} + e_t. \tag{1.13}$$

To analyze only the long-run term:

$$\Pi z_{t-1} = \begin{pmatrix} \alpha_{11}\beta_{11} & \alpha_{11}\beta_{12} \\ \alpha_{21}\beta_{11} & \alpha_{21}\beta_{12} \end{pmatrix} \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} = \begin{bmatrix} y_{t-1}(\alpha_{11}\beta_{11}) + y_{t-1}(\alpha_{11}\beta_{12}) \\ x_{t-1}(\alpha_{21}\beta_{11}) + x_{t-1}(\alpha_{21}\beta_{12}) \end{bmatrix}, \tag{1.14}$$

equation (1.14) can be rewritten as:

$$\Pi z_{t-1} = \begin{bmatrix} \alpha_{11}(\beta_{11} Y_{t-1} + \beta_{12} y_{t-1}) \\ \alpha_{21}(\beta_{11} x_{t-1} + \beta_{12} x_{t-1}) \end{bmatrix}. \tag{1.15}$$

Equation (1.15) shows one cointegrating vector with its respective speed of adjustment terms $\alpha_{11}$and $\alpha_{12}$.

One objective of this study is to determine not only whether prices for fed cattle and hogs are cointegrated but also determine the number of cointegrating ranks, *r*, by using the Johansen method. Two null hypotheses are tested using the trace statistic and max statistic. The first null hypothesis is that a linear model of two price series has no cointegration. The second null hypothesis is that there exist *r* (= *n*-1) cointegrating vectors, where *n* is the number of variables.

There are two test statistics in Johansen's cointegration approach. The trace statistic is based on a likelihood ratio test. The trace statistic determines whether the trace is increased by adding more eigenvalues beyond the *r*th eigenvalue. For the trace statistic, the null hypothesis is that the number of cointegrating vectors is equal to *r, (r*=0) against the alternative null hypothesis that *r*>0. This statistic is calculated by:

$$\lambda_{trace}(r) = - T \sum_{i=r+1}^{n} ln(1 - \hat{\lambda}_{r+1}). \quad (1.16)$$

The max statistic tests the null hypothesis that *r*=0 against the alternative hypothesis that *r*=1 cointegrating vectors. The test consists of ordering the largest eigenvalues in descending order and considering whether they are significantly different from zero. In order to estimate how many of the eigenvalues are significantly different from zero, the max statistic is calculated by:

$$\lambda_{max}(r, r+1) = - T \ln(1-\hat{\lambda}_{r+1}). \quad (1.17)$$

Johansen's cointegration tests report two different estimates from different VECM ($p$) equations. One result is reported under the condition that there is a separate drift but no separate linear trend in VECM ($p$) form. This is written by:

$$\Delta z_t = \alpha\beta' z_t + \sum_{i=1}^{p-1} \Phi^*{}_i \, \Delta z_{t-1} + \delta_0 + \epsilon_t. \qquad (1.18)$$

Another result is reported under the condition that there is no separate drift in the VECM ($p$) form but a constant enters only via the error correction term. This is written by:

$$\Delta z_t = \alpha(\beta', \beta_0)(z_{t-1}, 1)' + \sum_{i=1}^{p-1} \Phi^*{}_i \, \Delta z_{t-1} + \epsilon_t. \qquad (1.19)$$

For fed cattle and hogs, this paper allows no separate drift in the VECM ($p$) form, but allows a constant via the error correction term, (1.19).

Based on the ADF test, cointegration tests were estimated. In this paper, cointegrating vectors are important estimates to confirm the existence of cointegration. When the liner combinations include more than two nonstationary variables, it is possible that there exist more than one cointegrating vectors. Cointegrating vectors imply that the economic system is stable.

***Fed cattle*** - Table 4 presents the results of cointegration tests for fed cattle. For each case, the null hypothesis is rejected if the test statistic is larger than the critical value. In bivariate models, according to the trace statistic, the first null hypothesis is rejected that prices are not cointegrated, ($r$=0), at the 5% significance level.

**Table IV-3. Johansen's Cointegrating Tests for Fed Cattle**

| | Trace statistic | | | Max statistic | | |
|---|---|---|---|---|---|---|
| Variables | $H_0$ | $\lambda_{trace}$ | 5% Critical Value | $H_0$ | $\lambda_{max}$ | 5% Critical Value |
| Bivariate model | | | | | | |
| Negotiated cash price | r=0 | 35.98** | 19.99 | r=0 | 32.45** | 15.67 |
| Forward contract price | r=1 | 3.53 | 9.13 | r=1 | 3.53 | 9.24 |
| | | | | | | |
| Negotiated cash price | r=0 | 94.16** | 19.99 | r=0 | 84.40** | 15.67 |
| Negotiated grid | r=1 | 9.75** | 9.13 | r=1 | 9.75** | 9.24 |
| | | | | | | |
| Negotiated cash price | r=0 | 107.74** | 19.99 | r=0 | 104.01** | 15.67 |
| Formula price | r=1 | 3.72 | 9.13 | r=1 | 3.73 | 9.24 |
| | | | | | | |
| Multivariate model | | | | | | |
| Negotiated cash price | r=0 | 115.15** | 53.42 | r=0 | 62.99** | 28.14 |
| Forward contract price | r=1 | 52.16** | 34.80 | r=1 | 25.59** | 22.00 |
| Negotiated grid price | r=2 | 26.58** | 19.99 | r=2 | 22.72** | 15.67 |
| Formula price | r=3 | 3.65 | 9.13 | r=3 | 3.65 | 9.24 |

Notes: Double (**) indicates the rejection of null hypotheses that there are cointegrating vectors at the 5% significance level. *r* is the number of cointegrating rank.

To confirm the number of cointegrating vectors, one tests the second null hypothesis. The second null hypothesis that there are at most one cointegrating vector, ($r$=1), is failed to reject at the 5% significant level. However, in the model of negotiated cash prices and negotiated grid prices, the second null hypothesis is rejected at the 5% significance level. That is, this paper found more than one cointegrating vector in the model of negotiated cash prices and negotiated grid prices.

To make results from the trace statistic robust, the max statistic was also conducted in the bivariate models for fed cattle. The first null hypothesis that $r$=0 is rejected against the alternative hypothesis that $r$=1. However, results failed to reject the second null hypothesis that $r$=1 against the alternative hypothesis that $r$=2, except for the model of negotiated cash prices and negotiated grid prices. In the model of negotiated cash prices and negotiated grid prices, the result rejects the second null hypothesis that *r*=1; namely, this paper found two cointegrating vectors. It is not possible that a bivariate model can have two cointegrating vectors. Thus, this paper can conclude that those prices are not cointegrated.

Finally, from the two statistics it can be concluded that prices for fed cattle are cointegrated, and there is one cointegrating vector in bivariate models except for the model of negotiated cash price sand negotiated grid prices for fed cattle.

In the multivariate model, one also tests both trace and max statistics. According to the trace statistic, the first, second, and third null hypotheses that *r*=0, *r*=1, and *r*=2 are rejected at the 5% significance level. However, the fourth null hypothesis that there are 3 cointegrating vectors, (*r*=3), at the 5% significance level couldn't be rejected. Thus, for fed cattle, the multivariate model has 3 cointegrating vectors. Based on the max statistic, the null hypotheses that *r*=0, *r*=1, and *r*=2 are rejected at 5% significance level. However, the fourth null hypothesis could not be rejected at the 5% significance level that the number of cointegrating ranks is 3, against the alternative null hypothesis that there are 4 cointegrating vectors. In the multivariate model for fed cattle, this paper found that there are three cointegrating vectors.

***Hogs*** - Table 5 shows the results of cointegration tests for hogs. For hogs, in bivariate models, according to the trace statistic, the first null hypothesis is rejected that all prices are cointegrated, (*r*=0), at the 5% significance level. To confirm the number of cointegrating vectors, the second null hypothesis is tested. The second null hypothesis that there are at most one cointegrating vector, (*r*=1), is failed to reject at the 5%

significant level. Results show that there is at most one cointegrating vector in each bivariate model.

**Table IV-4. Johansen's Cointegrating Tests for Hogs**

| | Trace statistic | | | Max statistic | | |
|---|---|---|---|---|---|---|
| Variables | $H_0$ | $\lambda_{trace}$ | 5% Critical value | $H_0$ | $\lambda_{max}$ | 5% Critical value |
| Bivariate model | | | | | | |
| Negotiated cash price | r=0 | 19.62** | 19.99 | r=0 | 15.97** | 15.67 |
| Other formula price | r=1 | 3.65 | 9.13 | r=1 | 3.44 | 9.24 |
| | | | | | | |
| Negotiated cash price | r=0 | 49.50** | 19.99 | r=0 | 41.21** | 15.67 |
| Swine formula price | r=1 | 8.23 | 9.13 | r=1 | 8.22 | 9.24 |
| | | | | | | |
| Negotiated cash price | r=0 | 21.81** | 19.99 | r=0 | 14.49** | 15.67 |
| Other purchase price | r=1 | 7.10 | 9.13 | r=1 | 7.06 | 9.24 |
| | | | | | | |
| Multivariate model | | | | | | |
| Negotiated cash price | r=0 | 72.87** | 53.42 | r=0 | 37.21** | 28.14 |
| Other formula price | r=1 | 35.66** | 34.80 | r=1 | 21.78** | 22.00 |
| Swine formula price | r=2 | 13.88 | 19.99 | r=2 | 11.16 | 15.67 |
| Other purchase price | r=3 | 2.71 | 9.13 | r=3 | 2.71 | 9.24 |

Notes: Double (**) indicates the rejection of null hypotheses that there are cointegrating vectors at the 5% significance level. *r* is the number of cointegrating rank.

To make results from the trace statistic robust, the max statistic was also tested in the bivariate models for hogs. The first null hypothesis is rejected that $r$=0 against the alternative hypothesis that $r$=1, but the statistic failed to reject the second null hypothesis that $r$=1 against the alternative hypothesis that $r$=2. Thus, it can be concluded there is one cointegrating vector in each bivariate model.

Finally, from the trace and max statistics it can be concluded that there is evidence of cointegration in prices for hogs as well as there is one cointegrating vector.

In the multivariate model, both trace and max statistics are calculated. According to the trace statistic, the first and second null hypotheses that $r$=0 and r=1 is rejected at the 5% significance level. However, the third null hypothesis, that the cointegrating ranks are two, could not be rejected at the 5% significance level. Thus, for hogs, the multivariate model has 2 cointegrating vectors in levels. Based on the max statistic, the first and second null hypotheses that $r$=0 and r=1 is rejected at 5% significance level. However, the third null hypothesis could not be rejected at the 5% significance level that the number of cointegrating rank is 2, against the alternative null hypothesis that there are 3 cointegrating vectors. In the multivariate model, prices are cointegrated and there are 2 cointegrating vectors.

Based on Johansen cointegration tests, this paper estimated whether or not prices for fed cattle and hogs are cointegrated and there are $n$-1 cointegrating vectors. In bivariate and multivariate models for hogs, this paper found that prices are cointegrated, and there is one cointegrating vector in bivariate models. In multivariate model, prices are cointegrated, and there are two cointegrating vectors. However, in a bivariate model of negotiated cash prices and negotiated grid prices for fed cattle, this paper could not find that prices are cointegrated. This paper might concern that this bivariate model include negotiated grid prices that have the number of missing prices. Such missing prices might affect the results from cointegration tests.

## Stock-Watson's Common Trends

Stock and Watson (1988) stated that the parameters of the cointegrating vector must be such that they purge the trend from the linear combination. That is, any linear combination of the two variables contains a trend. Consider two cointegrated variables $y_t$ and $x_t$ :

$$y_t = z_t + u_t, \tag{1.20}$$

$$x_t = w_t + v_t. \tag{1.21}$$

where $z_t$ and $w_t$ are random walk processes representing stochastic trends, and $u_t$ and $v_t$ are stationary processes. The linear combination of these two variables can be written:$y_t - \ ax_t,$ (1.22)

where $a \neq 0$.

Assume for simplicity that $a = 1$

$$y_t - x_t = (z_t - w_t) + (u_t - v_t), \tag{1.23}$$

The random walk component must be zero, $z_t - w_t = 0$, because those variables are cointegrated. That is, cointegration of $y_t$ and $x_t$ implies that they share the same common stochastic random walk component. If there are n cointegrated series with cointegrating rank $r < n$, then these series have $n$-$r$ common trends ($m$=$n$-$r$).

In the Stock-Watson test, the null hypothesis is that there are $m$ common trends ($n$-$r$=$m$) against the alternative that there are $m$-1 trends. Testing for cointegrating vectors in Johansen's cointegration tests is roughly similar to testing for common trends in the Stock-Watson cointegration test. The Stock-Watson test is estimated by using the kernel method. When the test statistics are more negative than the critical value, the test rejects the null hypothesis that there are $m$ common trends against the null hypothesis that $m$-1 (less than $m$).

***Fed cattle*** - Table 6 displays the results from the Stock-Watson's common trends test for fed cattle. In the bivariate models, except for the model of negotiated cash prices and negotiated grid prices, the results failed to reject at the 5% significance level the first null hypothesis that there is one common trend. However, the second null hypothesis that there are two common trends is rejected at the 5% significance level against the alternative null hypothesis that there is one common trend. Therefore, this paper can conclude that there is one common trend in bivariate models except for the model of negotiated cash prices and negotiated grid prices. In the bivariate model of negotiated cash prices and negotiated grid prices, the results failed to reject the null hypothesis that there is one common trend. It implies that those prices are not cointegrated.

**Table IV-5. Stock-Watson's Common Trends Using the Kernel Method for Fed Cattle**

| Variables | $H_0(m)$ | $H_a(m-1)$ | Test results | 5% Critical value | Lag |
|---|---|---|---|---|---|
| Bivariate models | | | | | |
| Negotiated cash price and | 1 | 0 | -7.04 | -14.10 | 4 |
| forward contract price | 2 | 1 | -99.46* | -23.00 | |
| Negotiated cash price and | 1 | 0 | -15.22* | -14.10 | 3 |
| negotiated grid price | 2 | 1 | -95.04* | -23.00 | |
| Negotiated cash price and | 1 | 0 | -7.92 | -14.10 | 4 |
| formula price | 2 | 1 | -203.63* | -23.00 | |
| Multivariate model | | | | | |
| Negotiated cash price, | 1 | 0 | -11.46 | -14.10 | 3 |
| forward contract price, | 2 | 1 | -17.99 | -23.00 | |
| negotiated grid price, and | 3 | 2 | -104.89* | -31.50 | |
| formula price | 4 | 3 | -215.91* | -39.30 | |

Note: Single (*) indicates the rejection of the null hypothesis of *m* common trends at the 5% significance level. *m* is *n-k.*

***Hogs*** - Table 7 displays the results from the Stock-Watson's common trends test for hogs. In the bivariate models for hogs, the results fail to reject the first null hypothesis that there is 1 common trend at the 5% significance level. However, the test rejects the second null hypothesis that there are 2 common trends at the 5% significance level. Therefore it can be concluded that the individual bivariate models for hogs have one common trend at the 5% significance level.

**Table IV-6. Stock-Watson's Common Trends Using the Kernel Method for Hog**

| Variables | $H_0(m)$ | $H_a(m-1)$ | Test Results | 5% Critical value | Lag |
|---|---|---|---|---|---|
| Bivariate models | | | | | |
| Negotiated cash price and | 1 | 0 | -11.31 | -14.10 | 4 |
| other formula price | 2 | 1 | -28.44* | -23.00 | |
| Negotiated cash price and | 1 | 0 | -12.51 | -14.10 | 4 |
| swine market formula price | 2 | 1 | -183.32* | -23.00 | |
| Negotiated cash price and | 1 | 0 | -11.91 | -14.10 | 4 |
| other purchase price | 2 | 1 | -33.39* | -23.00 | |
| Multivariate model | | | | | |
| Negotiated cash price, | 1 | 0 | -11.54 | -14.10 | 4 |
| other formula price, | 2 | 1 | -17.98 | -23.00 | |
| swine market formula price, and | 3 | 2 | -42.34* | -31.50 | |
| other purchase price | 4 | 3 | -201.97* | -39.30 | |

Note: Single (*) indicates the rejection of the null hypothesis of *m* common trends at the 5% significance level. *m* is *n-k*.

In the multivariate model for hogs, the test statistic for testing for three versus two common trends is more negative (-42.34) than the critical value (-31.50). The test rejects the third null hypothesis, which means that price series for hogs have two common trends. Thus, it can be concluded that there is one common trend in the bivariate models for hogs, and there are two common trends in the multivariate model.

The results from Johansen's cointegration tests and the results from the Stock-Watson approach are compared. One could expect that the number of cointegrating vectors would correspond with the number of common trends form the Stock-Watson test, and these two tests would strongly support the evidence of cointegration. However, in fed cattle case, the number of cointegrating vectors from the Johansen's approach did not correspond with the number of common trends from Stock-Watson's approach in the multivariate model for fed cattle. This paper found three cointegrating vectors from Johansen's tests, but found two common trends from the Stock-Watson test. Thus, their results do not match. A concern is that this multivariate model also included negotiated grid market prices. The missing negotiated grid prices might affect the results.

## Vector Error Correction Model (VECM)

The concepts of cointegration and vector error-correction models are closely related. To understand the long-run relationship among different component series, a vector error correction model (VECM) is appropriate. In this paper, VECM is based on the previous cointegration model, the equation (1.19).

Based on the presence of cointegration, this paper analyzed the long-run relationships between negotiated cash prices and individual AMAs prices. Ward et al (1998) and Schroeter and Azzam (2003) found a negative relationship between the spot market price and captive supply price. Based on previous studies, this paper expected that the relationship between the negotiated cash price and each AMA transaction price would be negative in the long-run for fed cattle. Also, one expected the same relationship for hogs because fed cattle and hogs have a similar market structure.

***Fed cattle*** - Table 8 presents the estimates of the β's (long-run parameters) and α's (the speed of adjustment coefficients) for fed cattle based on the cointegrated price series. The estimates of the β's can be expressed that one unit (1$/cwt) increase in the forward contract price leads to 0.99 (1$/cwt) decrease in the negotiated cash price in the model of negotiated cash prices and forward contract prices. Also, in the model of negotiated cash prices and formula prices, one unit increase in the formula price leads to 1.01 decrease in the negotiated cash price. In the multivariate model for fed cattle, the existence of cointegration was not clear because the results from Johansen's cointegration tests and the Stock-Watson test did not match each other. Therefore, this paper concludes that prices are not cointegrated in the multivariate model.

**Table IV-7. Results from the Long-run Equilibrium Relationship (β) and Adjustment Coefficient (α) Estimates for Fed Cattle**

| Variables | Parameter estimates |
|---|---|
| Bivariate models | Rank=1 |
| Long-run equilibrium relationship (β) | |
| Negotiated cash price | 1.00 |
| Forward contract price | -0.99 |
| Constant | 1.04 |
| Adjustment Coefficient (α) | |
| Negotiated cash price | -0.03 |
| Forward contract price | 0.16 |
| | |
| Long-run Equilibrium Relationship (β) | |
| Negotiated cash price | 1.00 |
| Formula price | -1.01 |
| Constant | 2.48 |
| Adjustment Coefficient (α) | |
| Negotiated cash price | -0.01 |
| Formula price | 0.51 |

***Hogs*** - Table 9 presents the estimates of the β's (long-run parameters) and α's (adjustment coefficients) for each model based on the presence of cointegration. The results for long-run parameters include a constant term in each model.

The long-run relationship for each bivariate model can be expressed as:

$$p_{NegCash} = 5.26 - 1.09\, p_{Othrform}, \tag{1.24}$$

$$p_{NegCash} = 1.89 - 1.04\, p_{swnform}, \tag{1.25}$$

$$p_{NegCash} = 38.93 - 1.61\, p_{othrpurch}. \tag{1.26}$$

The multivariate model for fed cattle can be expressed as:

$$p_{NegCash} = -0.19 - 0.03\, p_{Othrform} - 1.08\, p_{Swnform} + 0.1\, p_{Othrpurch} \text{(Rank=1)}, \tag{1.27}$$

$$p_{NegCash} = 81.71 + 1.35\, p_{Othrform} + 1.37\, p_{Swnform} - 5.15\, p_{Othrpurch} \text{(Rank=2)}. \tag{1.28}$$

**Table IV-8. Results from the Long-run Equilibrium Relationship (β) and Adjustment Coefficient (α) Estimates under the Restriction for Hogs**

| Variables | Parameter estimates | |
|---|---|---|
| Bivariate models | Rank=1 | |
| Long-run Equilibrium Relationship (β) | | |
| Negotiated cash price | 1.00 | |
| Other formula price | -1.09 | |
| Constant | 5.26 | |
| | | |
| Adjustment Coefficient (α) | | |
| Negotiated cash price | -0.08 | |
| Other formula price | -0.01 | |
| | | |
| Long-run Equilibrium Relationship (β) | | |
| Negotiated cash price | 1.00 | |
| Swine formula price | -1.04 | |
| Constant | 1.89 | |
| | | |
| Adjustment Coefficient (α) | | |
| Negotiated cash price | 0.18 | |
| Swine formula price | 0.40 | |
| | | |
| Long-run Equilibrium Relationship (β) | | |
| Negotiated cash price | 1.00 | |
| Other purchase price | -1.61 | |
| Constant | 38.93 | |
| | | |
| Adjustment Coefficient (α) | | |
| Negotiated cash price | -0.07 | |
| Other purchase price | 0.01 | |
| | | |
| Multivariate model | Rank=1 | Rank=2 |
| Long-run Equilibrium Relationship (β) | | |
| Negotiated cash price | 1.00 | 1.00 |
| Other formula price | -0.03 | 1.35 |
| Swine formula price | -1.08 | 1.37 |
| Other purchase price | 0.10 | -5.15 |
| Constant | -0.19 | 81.71 |
| | | |
| Adjustment Coefficient (α) | | |
| Negotiated cash price | 0.07 | 0.01 |
| Other formula price | -0.11 | -0.02 |
| Swine formula price | 0.31 | 0.01 |
| Other purchase price | 0.02 | 0.02 |

When the other formula price, swine market formula price, and other purchase price are increased by one unit, the negotiated cash price is decreased by 1.09 units (1$/cwt) and 1.04 units (1$/cwt), and 1.61 units (1$/cwt), respectively. There is a negative relationship between negotiated cash price and each price of AMAs in bivariate models. The results are consistent with a priori expectations that there is a negative relationship between the negotiated cash price and each AMA price. In the multivariate model for hogs, the sign of coefficients is mixed in both rank=1 and rank=2.

***Fed cattle* –** The results of the adjustment coefficient (α's) are also presented in table 8. The values of adjustment parameters, or overshooting parameters imply how quickly the system moves back to its underlying long-run equilibrium. From results of table 8 for fed cattle, in bivariate models, the speed of adjustment parameters for the negotiated cash price and the forward contract price are -0.03 and 0.16, respectively. The absolute value of the negotiated cash price is less than the value of the forward contract price. It indicates that the forward contract price moves back to its long-run equilibrium faster than the negotiated cash price. In the model of the negotiated cash price and formula price, the absolute value of the formula price is greater than the absolute value of the negotiate cash price. Thus, it can be conclude that the formula price moves back to its long-run equilibrium faster than the negotiated cash price. These results imply that negotiate cash prices are more stable than forward contracts prices and formula prices.

***Hogs*** - Speed of adjustment coefficients in the model of the negotiated cash price and other formula price are -0.08 and -0.01, respective. The absolute value of the negotiated cash price is greater than the value of the formula price, which means that the negotiated cash price moves backs to its long-run equilibrium faster than the other formula price. Also, in the model of negotiated cash price and other purchase price, the absolute value of negotiated cash price is greater than the other purchase price and thus the negotiated cash price moves backs to its long-run equilibrium faster than the other formula price. However, in the model of the negotiated cash price and swine formula price, the absolute value of the negotiated cash price is less than the value of the swine formula price. It means that the swine formula price moves back to its long-run equilibrium faster than the negotiated cash price. Therefore, it can be concluded that in first and third models, negotiated cash prices are more flexible than other formula prices and other purchase prices. However, the second model, negotiated cash prices are more stable than swine market prices.

In the multivariate model, each speed of adjustment coefficients for hogs is close to zero when $r$=2. If there is more than one cointegrating vector in a multivariate model, which means the economic system is more stable. When AMA prices move together, those prices become more stable.

Therefore, this paper concludes that when the fed cattle market enters long-run terms, the forward contract price and the formula price are more flexible than the negotiated cash price for fed cattle in bivariate models. For hogs, when the hog market comes to long run terms, the negotiated cash price is more flexible than the other formula price and other purchase price in bivariate models. In the multivariate model, in long-run prices tend to be stable.

## Causality Tests

One feature of VAR models is that the direction of causality can be tested. In this paper, Granger causality tests are based on the VECM. Each bivariate model has two variables, ($y_t$, $x_t$), and they affect each other with distributed lags. This paper determines whether (a) $x_t$ causes $y_t$,(b) $y_t$ cause $x_t$, and (c) whether there is a bi-directional feedback among two variables or there is a single direction. Equations (1.29) and (1.30) based on a VECM with (*p*) lags using ordinary least square regression produces parameter estimates:

$$x_t = a_0 - \alpha_1 x_{t-1} + \alpha_1 \gamma y_{t-1} + a_{11} \Delta x_{t-1} + a_{12} \Delta x_{t-2} + a_{21} \Delta y_{t-1} + a_{22} \Delta y_{t-2}, \quad (1.29)$$

$$y_t = b_0 - \alpha_2 x_{t-1} + \alpha_2 \gamma y_{t-1} + b_{11} \Delta x_{t-1} + b_{12} \Delta x_{t-2} + b_{21} \Delta y_{t-1} + b_{22} \Delta y_{t-2}. \quad (1.30)$$

The test of causality is whether the lags of one variable enter into the equation for another variable. This study tested the hypothesis that $a_{21} = a_{22} = 0$. In bivariate models for fed cattle with two lags, and in bivariate models for hogs with one lag, this paper tests the null hypothesis that lagged $y_t$ does not Granger cause lagged $x_t$.

For fed cattle and hogs, Granger causality was estimated with lagged error-correction terms where the prices are cointegrated in bivariate models. Appropriate lag lengths were automatically determined by the VECM form.

***Fed cattle*** - Table 10 displays results of long-run Granger causality for fed cattle. VECM form for fed cattle automatically chose 2 lags. In a bivariate model of the negotiated cash and forward contract prices with 2 lags, the null hypothesis of no causality is rejected at the 5% significance level. In the opposite direction, the null hypothesis of no causality is rejected at the 5% significance level. Namely, two weeks ago negotiated cash prices affect this week's forward contract prices, and two weeks ago forward contract prices affect this week's negotiated cash prices. Thus, it is concluded that the negotiated cash price and the forward contract price have bi-directional feedback because the cash market and futures market interact with each other.

**Table IV-9. Results of Long-run Granger Causality for Fed Cattle**

| Dependent variables | Direction | Independent variables (lags) | Test results |
|---|---|---|---|
| D_FwdCon | ⇐ | D_NegCash(1)<br>D_NegCash(2) | 79.70* |
| D_NegCash | ⇒ | D_FwdCon(1)<br>D_FwdCon(2) | 8.32* |
| D_Formula | ⇐ | D_NegCash(1)<br>D_NegCash(2) | 137.33* |
| D_NegCash | | D_Formula(2)<br>D_Formula(1) | 2.05 |

Notes: Single (*) indicates the rejection of the null hypothesis of no causality at the 5% significant level. The numbers inside parenthesis ( ) are chosen lag length.

In the bivariate model of the negotiated cash and formula prices with 2 lags, the results rejected the null hypothesis of no causality at the 5% significance level. In the opposite direction, the results fail to reject the null hypothesis of no causality at the 5% significance level. There, two weeks ago negotiated prices affect this week's formula price, but not vice versa. Thus, negotiate prices and formula prices have a single directional feedback. One might be concerned with the chosen two lags because last week's negotiated cash price affects this week's formula price. The result implies in long-run two week ago formula price is not an important element in price discovery.

***Hogs*** - Table 11 presents results of Granger causality for hogs using the *t*-test. In hog case, the VECM form chose one lag in the bivariate models. In the bivariate model of negotiated cash prices and other formula prices with one lag, the null hypothesis of no causality is rejected at the 5% significance level. Also, in the opposite direction, the null hypothesis of no causality is rejected at the 5% significance level. That is, last week's negotiated cash prices affect this week's other formula prices and vice versa. Those prices have bi-directional feedback because the other formula price is tied to futures market like forward contracts for fed cattle. In the model of the negotiated cash price and swine formula price with one lag, the results reject the null hypothesis of no causality at the 5% significance level. In the opposite direction, the results reject the null hypothesis of no causality at the 5% significance level. Also, negotiated cash prices and the swine formula prices have bi-directional feedback because the swine formula price is tied to cash market. In the model of negotiated cash market prices and other purchase prices with one lag, those prices also have bi-directional feedback.

**Table IV-10. Results of Long-run Granger Causality for Hogs**

| Dependent variables | Direction | Independent variables (lags) | Test results |
|---|---|---|---|
| D_OthrForm | ⟸ | D_NegCash(1) | 2.33* |
| D_NegCash | ⟹ | D_OthrForm(1) | 3.21* |
| D_SwneForm | ⟸ | D_NegCash(1) | 5.84* |
| D_NegCash | ⟹ | D_SwneForm(1) | 4.03* |
| D_OthrPurch | ⟸ | D_NegCash(1) | -3.16* |
| D_NegCash | ⟹ | D_OthrPurch(1) | -3.85* |

Notes: Single (*) indicates the rejection of the null hypothesis of no causality at the 5% significant level. The numbers inside parenthesis ( ) are chosen lag length.

This causality test was conducted based on the previous VECM results because this paper was concerned with how negotiated cash prices affect individual other procurement prices when prices enter the long-run term. In both cases, negotiated cash prices mainly affect individual other procurement prices, but the others do not affect the negotiated cash market prices because their base price is affected by several other factors. When AMA prices enter in long-run terms, cash market prices play an important role in price discovery.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

This paper estimated the long-run relationships between cash market prices and prices for AMAs using econometric time series analysis. These results show that negotiated cash market prices and individual prices for AMAs formed a long-run equilibrium in bivariate and multivariate models for fed cattle and hogs. That is, negotiated cash market prices and each AMA price do not move too far away from each other.

It was expected that cash market prices and negotiated grid prices for fed cattle would be cointegrated (have a long-run equilibrium). However, in this study, the existence of cointegration was not found in the model of the negotiated cash price and the negotiated grid price. It can be concluded that those price wander arbitrarily far away from each other. One possible reason those prices are not cointegrated is the number of observed prices in the negotiated grid price data series, 213 versa 364 for fed cattle prices.

In addition to estimating cointegration, this study also examined the cointegrating vectors and common trends by using alternative cointegration approaches. The number of cointegrating vectors and common trends strongly support the existence of cointegration, and their numbers imply that AMAs prices are stable in the long-run. It was expected that the number of cointegrating vectors testing for the Johansen approach should correspond with the number of common trends testing for the Stock-Watson approach. In most models, their results matched each other based on the presence of cointegration. However, in the model including negotiated gird prices for fed cattle, this paper could not find that the prices are cointegrated.

Also, in multivariate models, there are at most two cointegrating vectors and two common trends for hogs. However, in the multivariate model for fed cattle, the number of cointegrating vectors does not correspond with the number of common trends. From the results of bivariate and multivariate models, one observation is that negotiated grid prices affect the results from cointegration tests.

The analysis of VECM shows that there is a negative relationship between AMA prices and negotiated cash prices in long-run for fed cattle and hogs. Also, in fed cattle case, forward contract prices and formula prices are more volatile than negotiated cash prices. But, in hog case, negotiated cash market prices are more volatile than other formula prices and other purchase prices except for swine market formula prices.

Based on the existence of a long-run equilibrium, this paper determined the direction of causality between the cash market prices and individual AMA prices for fed cattle and hogs. In the fed cattle case with two lags, the forward contract price and the negotiated cash price have bi-directional feedback. The result implies that cash market interacts with futures markets. However, the formula price and the negotiated cash price for fed cattle have a single directional feedback. It implies that the chosen two lags might not be appropriate in price discovery. In the hog case with one lag, the other formula price and the negotiated cash price, the swine market formula price and the negotiated cash price, and the other purchase price and the negotiated cash price for hogs have a bi-directional feedback, respectively. The chosen one lag for hogs is appropriate in price discovery, that is, last week's negotiated cash prices affect this week's individual AMA prices, and vice versa.

Therefore, it is concluded that negotiated cash prices and individual other procurement prices for fed cattle and hogs have a long-run relationship and negotiated cash prices can be a key element in price discovery when markets enter the long-run equilibrium.

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Findings and Conclusions: Negotiated cash market prices and individual prices for AMAs formed a long-run equilibrium in bivariate and multivariate models for fed cattle and hogs. That is, prices for fed cattle and hogs do not move too far away from each other. When prices enter in long-run terms, the prices had a negative relationship in bivariate models, and negotiated cash prices tended to be more stable than individual AMAs for fed cattle. However, in the hog case, some AMA prices became more stable than the negotiated cash prices. Negotiated cash prices played an important role in price discovery based on the long-run relationships among AMAs.

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