

AGRICULTURAL MARKETING  
AND  
RISK MANAGEMENT STRATEGIES:  
AN ANALYSIS OF THE UNITED STATES LIVESTOCK INDUSTRY

by

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B.A., Washington State University, 2006  
M.A., Washington State University, 2008

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics  
College of Agriculture

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

2014

## **Abstract**

This dissertation examines several different issues regarding pricing and contracting decisions as well as risk management practices affecting the United States livestock industry. The resulting policy and market implications are applicable to industry stakeholders in the beef cattle industry. Each topic is presented in the following chapters.

Chapter 1 uses time series techniques to identify movements in regional fed cattle prices under a mandatory price reporting system. Mandatory price reporting altered the structure of livestock markets by requiring supply and demand conditions to be reported twice daily thereby affecting the price discovery process. Results suggest the level of information flow and the transparency of prices increased, markets respond to new information quicker, and larger volume markets behave as a price leader to smaller markets with less volume.

Chapter 2 uses closeout data to measure the variability of profits in fed cattle production. A mean-variance approach was used to model yield risk factors relevant to and known at the time cattle are placed on feed. Results indicate yield factors were influenced by several preconditioning variables such as gender, placement weight, feedlot location, placement season, and overall animal health and vitality. Estimates from the yield equations were then used to simulate the overall ex-ante distribution of expected profits for the cattle feeder and the results provide information regarding the effect of production risk and price risk on cattle feeding profits.

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Approved by:

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# **Dedication**

To my brother Michael

## **Executive Summary**

This dissertation addresses several different areas of research related to the economics of agricultural marketing and risk management strategies with an emphasis in the United States livestock sector. Issues surrounding price reporting legislation and the representativeness of prices in contract design have a great effect on price discovery as well as the steps that should be taken to effectively manage both production risk and market risk for industry stakeholders. For example, cattle feeders face a tremendous amount of uncertainty regarding the expected profit outcomes of their operations which stems from the risks inherent in the production and marketing practices for feeder cattle. The ability to manage these risks begins with a proper understanding of the individual components to these risks and the subsequent extensions across different production stages and will eventually transcend to greater certainty of futures outcomes and the success of the individual operation.

Chapter 1, “Mandatory Price Reporting and its effects on Regional Fed Cattle Prices,” evaluates the movement of prices across regional fed cattle markets using several time series techniques. Mandatory price reporting was established to increase price transparency by requiring livestock processors to report marketing information twice daily to the United States Department of Agricultural – Agricultural Marketing Service and has had a noticeable impact of the transmission of market information between buyers and sellers of livestock. Market information is reflected in the product price. The amount of information available to the market, its timeliness, and reliability of the information raises concerns when there is structural change to the market as this can directly affect the management decisions of industry participants. Regional fed cattle prices are analyzed using tests for market integration, the effects of external

price shocks, and causality flows which offers a comprehensive approach to assessing the impact of mandatory price reporting on spatial market prices.

Five direct regional fed cattle markets were analyzed for this study and include: the Texas-Oklahoma Panhandle, Western Kansas, Nebraska, Colorado, and Iowa-Southern Minnesota. The results from this study show that mandatory price reporting legislation has been successful in its efforts into increase price transparency. This was evident from an increase in the strength of market integration and the speed of price adjustments that occurred between the respective geographic markets. By analyzing spatial market prices we gain insights into the current market structure and the information content of commodity prices. This information can then be applied to industry stakeholders in the development and application of more effective risk management strategies. It is the proper understanding price movements across geographic boundaries and the impact of new legislation on spatial market prices that is necessary if managers are to effectively manage market risk.

Chapter 2, “Measuring Profit Variability in Fed Cattle Production,” uses closeout data to measure the variability of profits in fed cattle production. The cattle feeding industry is an inherently risky business where even small swings in revenues cause profits for cattle feeders to vary greatly. Several factors contribute to the success of cattle feeding operations including the skills of the manager to allocate the costs associated with production and input and output prices. Physiological characteristics of the animal in question also play a major role in determining the success of the cattle feeder as the production performance and overall health and vitality of the animal will greatly affect the management decisions of the cattle feeder. Variability in prices and production lead to fluctuations in cattle feeding profits causing the cattle feeder to seek out

more effective risk management strategies. Quantifying production and market risk is essential to the development of risk management strategies.

A mean-variance approach is applied to model yield risk factors relevant to cattle feeders and known at the time cattle are placed on feed and this information is then used to illustrate the effects of profits for a given cattle feeder in order to gain perspective on the individual sources of risk. The time cattle are placed on feed, geographic location of a given feedlot, gender, and the weight of the animal at the time cattle are placed into the feedlot will influence the yield performance of the animal. Yield performance is characterized by an animal's ability to convert feed into weight gain, the amount of average weight gained per day, costs of veterinary services, and the mortality rate. Simulation methods were used to derive ex-ante profit distributions conditional on the risk factors to evaluate the effects of yield and price shocks on the distributional characteristics of cattle feeding profits. The results show that as prices become more volatile the variation in cattle feeder profit increases. Understanding why cattle feeding profits vary so dramatically help us develop more effective risk management strategies for the cattle feeder.

Each chapter addresses several different areas of livestock marketing including: how enacted price reporting legislation intended to enhance market transparency translates across regional fed cattle markets; how fed cattle profits are affected by the management decisions of the cattle feeder; and how declining trade volume can impact the purchasing decisions of buyers and sellers. Together these chapters provide insights into the current and future structure of livestock markets and the mechanisms involved in managing risk. The results from these studies will help industry professionals implement more effective management strategies by evaluating the level of transparency in prices (information flow and speed of adjustment) across geographic

boundaries following a regulatory change and accounting for a variety of production and marketing characteristics of fed cattle production that can explain why cattle feeding profits vary so widely.



# **Chapter 1 - Mandatory Price Reporting and its Effects on Regional Fed Cattle Prices**

## **Introduction**

The introduction of mandatory price reporting (MPR) has altered the way in which public price reporting is conducted within the United States livestock industry. The Livestock Mandatory Price Reporting Act of 1999 required processors to report market information on a variety of pricing and procurement methods to the United States Department of Agriculture - Agricultural Marketing Service (USDA-AMS). Throughout the past few decades the procurement market of the livestock industry has experienced a significant shift away from negotiated cash market transactions and placed greater emphasis on contracting and vertical integration. The level of consolidation between producers and processors has also increased. Cattle feeders have largely shifted away from smaller, localized, feedlots to larger more commercial operations while processors have shown a willingness to vertically integrate into different production stages (Pendell and Schroeder 2006). However, as the livestock industry began to transition toward privatization of its production practices, the method of reporting market conditions to the public did not. Therefore, concerns regarding the quality of market information as well as the transparency of the publically reported information arose and eventually led to the establishment of mandatory price reporting.

Evaluating regional fed cattle markets as they relate to price discovery allow us to gain an understanding of how fed cattle markets are defined geographically because of the high transportation costs associated with livestock production. Cattle are large, perishable, and not easily transported across production and consumption areas which are often separated, leading to

the segmentation of spatially separated markets (Pendell and Schroeder 2006). Furthermore, by evaluating the movement of prices across time we are able to identify the extent to which price shocks are relayed between locations. From a price discovery standpoint what this implies is that markets could reflect inaccurate price information and be a sign of market segmentation (Pendell and Schroeder 2006). Moreover, when cattle volumes oscillate in different directions between regions prices could diverge from one another as a result of poor information flow. These factors influenced concerns surrounding market transparency and whether price changes are fully representative of market conditions (Pendell and Schroeder 2006). Therefore understanding how price movements are transmitted between spatial market boundaries is essential to price discovery and the overall assessment of mandatory price reporting.

This chapter relies heavily on the concept of price discovery and as a result a distinction should be made between price discovery and price determination. These concepts are related, but have different interpretations. Price determination refers to the interaction between supply and demand to arrive at a market price level. Supply determinants would include the price of inputs to production, technology, and the price of outputs from production. Demand determinants would include the price of the finished product, the price of competing products, consumer income, and the taste and preferences of the consumer. These forces interact with each other to reach a specified market price. When market prices are declining or considered low then concerns regarding price discovery begin to arise (Schroeder et al. 1997).

Price discovery begins at the market price level and is concerned with the fluctuations of prices around the market price caused by the interaction between individual buyers and sellers. Price discovery refers to the process of arriving at an individual transaction price determined by the interaction of the parties involved (Schroeder and Minter 1999). When imprecise

information exists among buyers and sellers price discovery becomes increasingly ambiguous because decisions are based on uncertain expectations and a particular parties interpretation of market conditions (Schroeder and Mintert 1999). Transaction prices fluctuate around the market price level and due to characteristics of the commodity (quality attributes), quantity produced and sold, location and time the transaction takes place, the number and competitiveness of buyers and sellers, the timeliness and reliability of reported information, captive supplies, and the level of concentration among either buyers or sellers (Schroeder et al. 1997).

The timeliness and reliability of market information is of particular interest as it relates to how market information is reported to the public. Mandatory price reporting was introduced to enhance the timeliness and reliability of reported information by increasing the level and ease of access to a wider breath information through a single publically available channel. In the presence of uncertain market conditions individual buyers and sellers become more critical in their analysis of market fundamentals, the foundation of which is rooted in timeliness and reliability of the reported information. How market information is collected and analyzed implies that both buyers and sellers must possess a familiarity of current market conditions and expectations of demand and supply outcomes to be effective in price discovery (Schroeder and Mintert 1999). If information asymmetries exist then one party may realize less than favorable prices as a result of being less informed. The problem that is exacerbated when either party is more concentrated.

The processing industry for fed cattle is heavily concentrated within United States which tilts the balance information in favor of processors when they negotiate transaction prices with individual producers. The four-firm concentration ratio for processors of fed cattle is over 80 percent (Pendell and Schroeder 2006). If producers (sellers) are going to be successful when

negotiating the transaction price of their cattle with processors (buyers) they need to have continual and ready access to timely and reliable information sources in an effort to equalize the balance of information between negotiating parties (Schroeder and Mintert 1999).

The objective of this study is to identify the overall effectiveness of a mandatory price reporting system by evaluating movements among regional fed cattle prices in an effort to capture any material influence from the introduction of mandatory price reporting in terms of the timeliness and reliability of publically reported market information. Prior to mandatory price reporting all market information was submitted on a voluntary basis and did not include much of the new information reflected by the changes in a progressing market environment. Mandatory price reporting forced processors to provide wider information set and increase the transparency of publically reported information as a result. By evaluating price movements across time and geographic boundaries we gain an understanding of the ability of mandatory price reporting to enhance the timeliness and reliability of publically reported information and how information is transmitted across spatially distant markets.

### **History of Public Price Reporting**

Prior to mandatory price reporting, livestock producers were forced to rely on the USDA-AMS livestock market news reports for information on fed cattle prices. The reports were created from prices that were reported to the USDA – AMS on a voluntary basis by packers, producers, feedlot operators, and others (Pendell and Schroeder 2006). Overtime cattle feedlots and processing markets became increasingly concentrated and adopted new procurement methods that were not reported within the voluntary price reports. Traditional cash market transactions have declined and procurement methods have shifted toward the use of contracts and formula pricing agreements.

Mandatory price reporting was enacted in response to the added complexity of the new procurement methods in an effort to ease the data collection process by USDA-AMS and provide a publicly quoted price for livestock and livestock products with greater transparency. This led to the implementation of the Livestock Mandatory Reporting Act of 1999 which established a mandatory system for reporting public marketing information within the United States livestock industry.

Public market reporting was created for several reasons and includes: questions regarding competition, market efficiency, and fairness; and the desire by the federal government to obtain information on market conditions to study and observe the behavior in agricultural markets in an effort to properly manage incentives under the Food Production Act during World War I (Ward 2006). This led to the development of the Bureau of Markets within United States Department of Agriculture which was designed to facilitate the distribution of market information of agricultural commodities. It was not until after the Second World War that a comprehensive system of public market reporting was established under the Agricultural Marketing Act of 1946 (Ward 2006). The Agricultural Marketing Service (USDA-AMS) currently oversees the marketing of agricultural commodities authorized by the Agricultural Marketing Act of 1946.

Over time the structure of the livestock market and purchasing practices changed as markets became more decentralized and data collection became more difficult. As various types of contract transactions began to increase and cash transactions began to decline, the ability to maintain a current and relevant database that represented an evolving procurement market became difficult and concerns regarding privacy and market transparency increased (Ward 2006). These market trends also led to concerns of thin markets, asymmetric information for price discovery, and non-competitive markets. While under the voluntary price reporting system

participants were allowed to objectively report market information making a standardized system of reporting increasingly more problematic (Ward 2006). It was these concerns that led to the development and enactment of the Livestock Mandatory Reporting Act of 1999.

In April 2001, the Livestock Mandatory Price Reporting Act of 1999 officially went into effect and required meat packing plants that slaughter at least 125,000 head of cattle, 100,000 head of swine, or slaughter and/or process 75,000 head of lambs or more annually twice daily to the USDA – AMS; reported information included: pricing information, contracting, formulated sales, as well as supply and demand conditions (Pendell, Schroeder 2006). The 1999 Act was also intended to improve the reporting capabilities of the USDA – AMS and promote competition for livestock and livestock products by creating a network that balances information asymmetries between parties (Federal Register 2010). The Livestock Mandatory Price Reporting Act of 1999 replaced the voluntary price reporting system with a mandatory system and their contrasts are the focus of this study.

The 1999 Act was intended to last for five years and was set to expire in December of 2004, but was temporarily extended until September 30, 2005. It was on this date in September that the 1999 Act was terminated because congress could not reach an agreement on the length of the extension. However, information on market conditions continued to be reported voluntarily by the USDA – AMS. The United States Government Accountability Office (GAO) published a review of MPR in December of 2005 and made several recommendations for improvement and includes the following: (1) improvements in market reporters' instructions, and (2) auditing transactions from reported errors by meat processors (Pendell and Schroeder 2006).

The Reauthorization Act was enacted legislation by Congress in October 2006 that reestablished mandatory price reporting through September 30, 2010. The Reauthorization Act

effectively reinstated the regulatory authority for the continued operation of the Livestock Mandatory Price Reporting program in addition to several changes including the separation of the reporting requirements for sow and boars from barrows and gilts. However, on September 28, 2010 the Livestock Mandatory Price Reporting Act of 2010 was instated and mandatory price reporting was extended for an additional five years and included provisions for the mandatory price reporting of wholesale pork cuts (Federal Register 2010).

## **Literature Review**

There is a fairly extensive literature on price discovery in livestock markets pertaining to the value of market information, market efficiency in the cash and futures market, competition, and market structure. However, until mandatory price report went online very few articles addressed price reporting alone and economists seemed to accept voluntary price reporting data as accurate and a viable means to data collection (Ward 2006). This raises the question as to whether the information reported while under the voluntary system properly reflected market conditions either temporally or spatially and if mandatory price reporting has provided any material influence on price discovery (Ward 2006).

Fausti and Diersen (2004) examined the transparency of prices for dressed steers in the voluntary price reporting system. The cointegration property and an error correction model were applied to assess the long-run equilibrium relationship and short-run disequilibrium adjustment process between mandatory reported cash prices in South Dakota and voluntary reported cash prices in Nebraska. The analysis was intended to investigate whether a thin cash market or strategic price reporting by processors resulted in degraded transparency in the voluntary system. Transparency was found not to be degraded and the voluntary system of reporting did contribute

to price discovery by promoting the transparency of prices. Furthermore, there was no evidence to suggest processors strategically misrepresent reported information.

Franken, Parcell, and Tonsor (2010) examined the impact of mandatory price reporting in the cash market and lean-hog futures market for hogs located in the mid-central region of the United States. The analysis included a set of pairwise comparisons of the long-run equilibrium relationship and the responsiveness of prices that are spatially separated. Markets were integrated before and after mandatory price reporting, however, the level of market integration did not change and markets were not fully integrated, implying markets did not adjust to price changes on a one-for-one basis. Markets were found to adjust to price changes more slowly under the mandatory system. However, the authors acknowledge a possible coincidence between the slower price adjustments and declining cash market trade volume for hogs and this result may not be reflective of mandatory price reporting *per se*.

Pendell and Schroeder (2006) used data from USDA-AMS reports of fed cattle market price data from five regional U.S. markets that ranged from January 1992 to June 2005. The authors used time series techniques to evaluate the effects of mandatory price reporting on spatial market integration fed cattle markets. Their results indicated that five regional markets have been, and remain, highly cointegrated since the initial inception of mandatory price reporting. They also conclude that all five of the U.S. regional markets have become even more integrated following the establishment of mandatory price reporting, indicating that MPR has increased the flow and transparency of market information.

Grunewald, Schroeder, and Ward (2002) examined the impact of livestock mandatory price reporting from the perspective of producers'. The framework is based on cattle feeders' perceptions and how the characteristics of feedlot influence the management decisions of the



feedlot operation to gain an understanding of the effectiveness of the mandatory system from the producers' perspective. A survey was distributed to feedlot operations located in Iowa, Kansas, Nebraska, and Texas and management decisions were quantified according to the perceived benefits to the beef industry, informational content, and the ability of feedlots to negotiate transaction prices with processors. They found that cattle feeders were generally indifferent or slightly negative toward the new legislation when asked how MPR would influence them operationally. Furthermore, feedlot characteristics showed little impact on the management decisions of a given operation, suggesting that the usefulness of mandatory price reporting is questionable.

Lee and Kim (2007) examined price discovery among regional fed cattle markets to identify the casual structure between spatially distant fed cattle cash prices using weekly prices from February 2002 to July 2006. An analysis of casual flows offers an opportunity to identify leaders in the price discovery process and thus serve as a primary source of market information to an industry. The Kansas market was identified as a price leader, a central source of market information, and had the greatest influence among Texas, Colorado, and Nebraska prices. The Iowa-Southern Minnesota market did not have the same level of influence as the Kansas market, however, was identified as a price leader to Nebraska and Colorado markets in price discovery.

Bailey and Brorsen (1985) examined the dynamic relationships between regional fed cattle prices using causality tests. The Texas Panhandle led the price discovery process and prices adjusted to new information weekly. Prices were also found to be interdependent suggesting packers may not obtain additional market power in their pricing practices from increased concentration alone.

Schroeder and Goodwin (1990) investigated the lead-lag relationships present in the regional price discovery process. Direct and terminal trade cattle markets were examined using a multivariate vector autoregressive framework. Larger volume cattle markets fully responded within a week of the price change whereas the smaller volume markets within two to three weeks of the initial change in prices.

Goodwin and Schroeder (1991) analyzed cointegrating relationships and spatial linkages for 11 different regional slaughter cattle markets within the United States. They found that increased cointegration paralleled structural changes in the livestock industry. Cointegration relationships are significantly influenced by several factors including: the geographical distance between cattle markets, level of market concentration, trade volume, and market types.

This study extends previous research by addressing public price reporting legislation and price discovery in a several different ways. Previous research in this area has largely focused on the relationship of prices in the context of a long-run equilibrium and causal flows between spatially separated markets in a limited number of locations. Pendell and Schroeder (2006) is the only other study that examined spatial fed cattle market prices in the context of MPR and price discovery for the same five markets considered here, but its assessment only addresses market integration from the perspective of cointegration. Lee and Kim (2007) investigated causal flows, but did not take into account price behavior under the voluntary system. This study evaluates the impact of mandatory price reporting on the five largest (trade volume) fed cattle regions and identifies pricing relationships from several different perspectives and draws inferences not only regarding mandatory price reporting, but to the voluntary system as well. Analyzing public price reporting in this manner should not only add to our understanding of how spatial market prices are linked, but also to the effectiveness of price reporting legislation under two different systems.

This approach should provide for a more robust assessment of price transmissions under two different regulatory regimes.

## **Methods and Procedures**

### ***Cointegration and Stationarity Tests***

Regional market prices, if cointegrated, should not diverge from each other in the long-run (Pendell and Schroeder 2006). Before testing for spatial market relationships, stationarity tests need to be performed for each individual price series; this was done by the Augmented Dickey Fuller (ADF) test. If we fail to reject the null hypothesis of a unit root, then the price series is non-stationary. If prices are stationary in their first differences and non-stationary in their levels, then one can proceed to test a cointegrating relationship. The stationarity of time series data is important because of the notion of spurious regression which will invalidate the regression results when the regression is performed on non-stationary variables.

Spurious regression as described by Granger and Newbold (1974) involves regression results that appear valid in the sense that the model produces a high  $R^2$  value and significant  $t$ -statistics, but the regression maps relationships that do not actually exist. For example, if the number of observations  $n$  approaches infinity, a spurious regression will reject the null hypothesis that  $\alpha_2 = 0$  (equation 1.1) with a probability of one. Furthermore,  $R^2$  will not converge to zero and instead converge to a random, positive number that varies between samples (Davidson and MacKinnon 2004). This can occur by running a regression on data that are non-stationary and a procedure needs to be applied to transform the data to a stationary process. First differencing the each individual price series transforms the data from non-stationary to stationary by subtracting the datum in a price series from its previous value. For example, if  $x$  represents a given prices series then  $x_t$  is the value is  $x$  at time  $t$  and the first difference value of  $x$  is identified

as  $x_t - x_{t-1}$ . When the price series are stationary in the first differences they are said to be integrated of order 1.

The next step is to test for a cointegrating relationship using two procedures proposed by both Engle-Granger (1987) and Gregory-Hansen (1996). The Gregory-Hansen procedure allows for the inclusion of structural breaks that may have influenced these relationships in a post-MPR environment. After first differencing the individual price series the estimation procedure for both proposed models involve: 1) estimate the specified equation using Ordinary Least Squares (OLS) and obtain estimated residuals, and 2) perform an ADF unit root test on the estimated residuals. If we fail to reject the null hypothesis of a unit root then the two price series are non-stationary, implying markets are not cointegrated. Any structural change in the price series could result in a significant change among the cointegration parameter or even the existence of cointegrating relationships (Pendell and Schroeder 2006).

The Engle-Granger model is specified in equation 1.1:

$$y_t = \alpha_0 + \alpha_1 x_t + e_t \quad (1.1)$$

where  $\alpha_0$  and  $\alpha_1$  represent the respective intercept and slope coefficients,  $y_t$  and  $x_t$  are the individual price series identified by each regional fed cattle market price, and  $e_t$  is the disturbance term. The values for  $y_t$  and  $x_t$  are first differenced to account for stationarity of the given price series they represent. This model allows for cointegration to be tested without controlling for structural breaks and information can be gained as to whether mandatory price reporting materially affected regional fed cattle prices by testing for a long-run equilibrium relationship between markets that are spatially separated.

The Gregory-Hansen model is represented by equation 1.2:

$$y_t = \alpha_0 + \alpha_1 d_t + \alpha_2 x_t + \alpha_3 x_t d_t + e_t \quad (1.2)$$

where  $\alpha_0$  is the intercept term  $\alpha_1$  denote the change in the intercept after the regime shift,  $\alpha_2$  is slope coefficient prior to the regime shift,  $\alpha_3$  represent the change in the slope after the regime shift,  $d_t$  is a dummy variable that takes the value of 1 if after MPR and 0 otherwise,  $e_t$  is the disturbance term, and  $y_t$  and  $x_t$  denote the price series of the individual regional markets. The model adjusts for structural breaks through the intercept and slope coefficients with the addition of dummy variables at the time the break may have occurred (i.e. April 2001). Accounting for the impact of MPR in this manner provides an opportunity to capture information on not only the material influence of MPR on prices, but the changes in the level of any cointegrating relationships as well.

The models described in equation 1.1 and equation 1.2 tests for the presence of a cointegrating relationship between two individual regional fed cattle price series and offer a chance to test several hypotheses. The first hypothesis is whether mandatory price reporting had any impact on the cointegrating relationship of spatial market prices. The results from equation 1.1 and equation 1.2 would suggest that mandatory price reporting had no effect on the behavior of regional fed cattle prices if all pairwise comparisons are identified as either cointegrated or not cointegrated. This result would imply that mandatory price reporting had no impact on the long-run equilibrium relationship among regional fed cattle prices. A second hypothesis is whether or not the strength of the cointegrating relationship changed with the implementation of mandatory price reporting and allows us to gain a perspective on the level of price changes that may have occurred.

Two approaches present themselves if we consider equation 1.2: 1) if  $\alpha_3$  is statistically different from zero, then we have a statistically reliable estimate that captures the level of price changes following the introduction of mandatory price reporting, 2) by comparing the

relationship between  $\alpha_2$  and  $\alpha_3$  provides information regarding the strength of the cointegrating relationship. For example, if  $\alpha_2 + \alpha_3 = 1$  then prices are fully integrated, implying that prices move closer to a one-to-one basis post mandatory price reporting. An increase in the level of integration could be evidence of increased information flow as a result of greater content and trust in reported information between markets following MPRs introduction as well as an elevation in market efficiency from greater access to market information.

### ***Impulse Response Functions***

Regional fed cattle markets are further analyzed to capture the movement of an exogenous shock on spatial market prices; a vector autoregressive (VAR) model was used to derive an error correction model for each market. Impulse response functions are a useful way to illustrate the response of a given variable when an exogenous shock of another variable enters the system and provide a means to assess the speed to which price adjustments occur among different regional fed cattle locations. If the data is separated such that one subsample is representative of the time period under voluntary price reporting and another subsample is reflective of the time period where mandatory price reporting prevailed then comparisons can be drawn between each public price reporting system. If price adjustments occur more quickly with the implementation of MPR then this would suggest that mandatory price reporting has enhanced the reliability and availability of market information. Following Enders (2004) the bivariate-first order VAR can be written in matrix form:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (1.3)$$

where  $y_t$  and  $x_t$  are assumed stationary  $e_{1t}$  and  $e_{2t}$  and are white noise errors. The time path of  $\{y_t\}$  is influenced by current and future realizations of the sequence  $\{x_t\}$ , alternatively, the time path of  $\{x_t\}$  is affected by current and future realizations of the sequence  $\{y_t\}$ .

The vector moving average representation (VMA) of the vector autoregressive model was used to estimate the impulse response functions. The VMA representation allows for the time path of various shocks to be mapped out on the variables defined within the specified VAR model and following Enders (2004) written as:

$$y_t = \mu + \sum_{i=0}^{\infty} \phi_i \varepsilon_{t-1} \quad (1.4)$$

The coefficients of  $\phi_i$  are used to generate the impact of  $\varepsilon_{yt}$  and  $\varepsilon_{xt}$  on the time paths of  $\{y_t\}$  and  $\{x_t\}$  where  $\phi_i$  can be interpreted as an impact multiplier representing the impulse response functions to the system. That is, the instantaneous effect of a one-unit change in  $\varepsilon_{xt}$  on  $y_t$  is captured by the coefficient  $\phi_{12}(0)$ . Future values can be obtained by generating these effects to subsequent periods. For example, updating by one period implies that  $\phi_{11}(0)$  and  $\phi_{12}(1)$  represent the effect of a one unit change in  $\varepsilon_{yt-1}$  and  $\varepsilon_{xt-1}$  on  $y_{t+1}$  (Enders 2004).

The order of the VAR model is identified by selecting the highest lag length. The lag length for the VAR system was selected using the Akaike Information Criterion (AIC) and calculated as:

$$AIC_i = \ln\left(\frac{SSE_i}{T}\right) + \frac{2(K_i)}{T} \quad (1.5)$$

where  $T$  is the total number of observations, and  $K_i$  is the total number of parameters. This method of model selection measures the trade-off between increases in the number of exogenous variables and the minimizing the sum of squared errors,  $SSE_i$ , (Griffiths, Hill, and Judge 1993).

Impulse response functions show the effect of an exogenous shock on the adjustment path of a given price series. In this way impulse response functions are used to analyze the response to the current and future values of set of variables from one unit increase in the current value of the VAR errors (Susanto et al. 2004). If individual prices are stationary then the impulse responses should converge to zero as time ( $t$ ) increases. Conversely, if the price series is

non-stationary and cointegrated, shocks to the system may have a permanent effect and the impulse response coefficients may not converge to zero (Frank, Garcia 2010).

There are two measures that would suggest whether or not mandatory price reporting improved the reliability of regional fed cattle prices: 1) whether the impact of an exogenous shock dissipates over time or has a permanent effect and 2) the time dimension allows us to observe how long the exogenous shock remains in the system. If prices converge to zero then price adjustments occur until the impact exogenous price shock filters out at some future point in time. Secondly, if price adjustments occur more quickly: the effect of the price shock will leave the system sooner, a plausible result when there is greater certainty surrounding price movements for a given market. In reference to mandatory price reporting: if both events are observed after MPR then there is evidence to suggest that market information has become more reliable and available in a post-MPR environment.

### ***Forecast Error Variance Decomposition***

In addition to impulse response functions, forecast error variance decompositions (FEVD) are also used to analyze the effects of various shocks to prices. The FEVD procedure is also calculated from the vector moving average representation of the VAR procedure and can provide useful information about the sources of volatility affecting the model. Variance decompositions provide a measure of the degree of exogeneity for a set of variables relative to another set of variables by computation of the expected k-step ahead squared predicted error of a variable created by an innovation in another variable (Schroeder and Goodwin 1990). Variance decompositions provided an estimate that can be interpreted by the amount of variance a given price series will have on another. Specifically, the variance of each price series is decomposed into the percentages attributable to each innovation (Frank and Garcia 2010).



The forecast error variance decompositions are analyzed by separating the data into two subsamples in the same manner described within the impulse response function section. Consequently, comparisons are drawn between the two sample periods to gain an understanding of the extent to which mandatory price reporting has influenced the volatility of regional fed cattle prices when an exogenous price shock enters the system. In the context of this study forecast error variance decompositions describe the degree regional fed cattle prices explain the unpredictable movement in prices relative to each other in the short-run. If the level of volatility changed with the implementation of mandatory price reporting then inferences can be made regarding the extent the regional cattle markets in question depend on each other for sources of information. Assuming mandatory price reporting increased the transparency of market information then regional fed cattle markets should explain less of the unexplainable movement in prices relative to other markets post-MPR.

### ***Granger Causality***

Regional fed cattle markets were analyzed using a two-variable (pairwise) Granger causality test to identify lead-lag relationships between markets. The classification of dominant (lead) and satellite (lag) markets can be defined as one market is more influential in the price discovery process (Garbade and Silber 1979). Lead markets are those that are able to assimilate the information more quickly and make little or no use of information formulated elsewhere (Koontz et al. 1990). Alternatively, lag markets rely on the more dominant markets as the primary source of information (Koontz et al. 1990).

The price discovery process is captured by selecting a homogeneous time period for the analysis and allowing for structural change by examining the dynamic pricing relationships over time. The idea of using the Granger causality tests is in establishing the temporal ordering of

markets in the price discovery process. This makes the Granger causality approach well suited for analyzing price discovery within agricultural markets (Koontz et al. 1990).

The two-variable causality model of a vector autoregressive framework for the price series can be represented by Granger (1969):

$$X_t = \sum_{j=1}^m a_j X_{t-j} + \sum_{j=1}^m b_j Y_{t-j} + \varepsilon_t \quad (1.6)$$

$$Y_t = \sum_{j=1}^m c_j X_{t-j} + \sum_{j=1}^m d_j Y_{t-j} + \eta_t \quad (1.7)$$

where  $X_t$  and  $Y_t$  are two individual stationary price series and  $\varepsilon_t$  and  $\eta_t$  are taken to be two white noise errors.

The measurement of the causal price flows and adjustments were estimated using Granger causality  $F$ -tests to test the following hypothesis:

$$H_0: a_{12}(1) = a_{12}(2) = \dots = a_{12}(K) = 0 \quad (1.8)$$

Rejection of the null hypothesis indicates that the discovery variable  $Y_t$  in the price series leads to the discovery of variable  $X_t$ . If price changes in market  $Y_t$  are found to lead price changes in market  $X_t$  with no significant feedback, then market  $Y_t$  will be referred to as dominant to market  $X_t$  and market  $X_t$  as a satellite of market  $Y_t$  (Schroeder and Goodwin 1990).

Feedback can be either asymmetric or symmetric depending on the extent to which, say, series  $X_t$  follows series  $Y_t$ . Koontz et al. (1990) describe asymmetric and symmetric feedback in the following way. Asymmetric feedback occurs when market  $X_t$  follows market  $Y_t$  closely, while maintaining a slight effect on prices in market  $Y_t$ ; therefore market  $Y_t$  will tend to weakly dominate market  $X_t$  in the price discovery process. Symmetric feedback exists when price changes between markets when  $X_t$  and  $Y_t$  are equivalent, indicating that both markets are of equal importance within the price discovery process.

The lead-lag pricing relationships are analyzed by separating the data between the periods in which the specified price reporting systems were imposed and comparing the results. An examination of Granger causality flows gives an opportunity to identify the extent to which regional fed cattle markets are more influential in the price discovery process relative to each other. The objective is to identify which markets, if any, are more (less) reliant on outside sources for market information and whether mandatory price reporting has had any material effect on this relationship. For example, if mandatory price reporting has enhanced the transparency of market information then regional fed cattle markets should be less reliant on movements (prices and volume) in other spatial cattle markets as a result of greater trust in the reliability and availability of market information provided by MPR.

## **Data**

A weekly weighted average price series for both dressed and live steers and heifers was collected from January 1992 to April 2011 for five regional cattle markets within the United States. These regions include: Iowa-Southern Minnesota Direct, Western Kansas Direct, Nebraska Direct, Texas-Oklahoma Panhandle Direct, and Colorado Direct and were obtained from the Livestock Marketing Information Center and the USDA-AMS price reports. These five regional markets represent the majority of fed cattle trade and have continuously reported market data since the start of mandatory price reporting. The data were separated into two subsamples to compare the difference between MPR and a voluntary system, January 1992 through April 2001 (voluntary price reporting) and April 2001 through April 2011 (mandatory price reporting).

The data used in this study represents a calculated weighted average of weekly dressed and live steer and heifer prices following the method outlined by Pendell and Schroeder (2006). First, dressed prices were converted to live prices for both steers and heifers by dividing the

national dressed weight for steers and heifers by the national live weight for steers and heifers then multiplying by their respective dressed prices and including a transportation cost adjustment by subtracting a \$0.50/cwt live weight, resulting in a converted dressed prices for both steers and heifers. Next, the converted prices for steers and heifers were combined with their respective live prices by calculating a weighted average of the converted dressed prices and live prices for both steers and heifers, giving a combined dressed and live price for both steers and heifers. The combined dressed and live prices for steers and heifers were then calculated to form a single composite price series for dressed and live steers and heifers for the region they represent. Composite prices are a weighted average of the combined dressed and live prices for steers and heifers that represent a single price series for a particular regional fed cattle market from which the prices originated.

## **Results**

### ***Cointegration and Stationarity Tests***

The first step in testing for long-run equilibrium relationships is to conduct unit root tests for each price series. The ADF unit root test, tests the null hypothesis that the individual price series contains a unit root (non-stationary). The results from the ADF test suggest that prices for all five regional fed cattle markets were non-stationary in levels and stationary in first differences at the 5 percent level. Stationary data implies that the mean and variance estimates are constant over time and concerns that arise from a spurious regression do not persist. Spurious regressions occur when a regression model, such as equation 1.1 and equation 1.2, identify statistical relationships that do not actually exist.

The results from the Engle-Granger cointegration test procedure indicate that all five regional fed cattle markets were pairwise cointegrated at the one percent level and the

corresponding test statistics are shown in table 1.1. The results imply that a long-run equilibrium relationship exists between each respective market and suggest that there is no need to test for a structural break as market prices are cointegrated. However, additional information can be gleaned by testing whether the strength of the cointegration property changed after the introduction of mandatory price reporting.

The Gregory-Hansen cointegration test procedure was used to control for the impact of a structural break and the results suggest that markets were pairwise cointegrated, however, the strength of the cointegrating relationship changed with the inclusion of mandatory price reporting (see table 1.1 and table 1.2 for estimation and test results). From table 1.2, Nebraska/W. Kansas model the estimated the pre-MPR coefficient ( $\alpha_2$ ) to be 0.9326 and the post-MPR level ( $\alpha_3$ ) to be 0.0667. Therefore, for a \$1/cwt. increase in the fed cattle price for the W. Kansas market would be an associated 0.9326 increase in the fed cattle price for Nebraska. This implies that following MPR; the Nebraska fed cattle market price follows the W. Kansas fed cattle price market more closely (i.e.  $0.9326 + 0.0667 = 0.9993$ ). The fed cattle prices of Nebraska and W. Kansas are closer to full integration (i.e. prices move closer one-for-one) when operating under mandatory price reporting.

A hypothesis test was applied to formally test for changes in market integration. The null hypothesis tests are defined as:

$$H_0: \alpha_2 = 1 \quad (1.9 - \text{pre-MPR hypothesis})$$

$$H_0: \alpha_2 + \alpha_3 = 1 \quad (1.10 - \text{post-MPR hypothesis})$$

Rejection of either null hypothesis would imply that a market was not fully integrated for the specified sample period.

The pre-MPR hypothesis test (equation 1.9) was rejected for all of the cattle markets except for Iowa-S. Minn./Nebraska, and W. Kansas/Texas-Ok. markets, suggesting that these

markets were fully integrated prior to MPR. The pairwise markets that were fully integrated post-MPR are not unexpected given the proximity of these locations and commonalities between cattle type. The null hypothesis specified by equation 1.10 was rejected for Colorado/Texas-Ok., Colorado/W. Kansas, and Colorado/Nebraska pairwise markets. Rejection of the null hypothesis would indicate that these pairwise markets were not fully integrated after the implementation of mandatory price reporting. However, if we consider the summation of the pre- and post-MPR coefficients ( $\alpha_2 + \alpha_3$ ) we find that each market produces a value closer to one, implying that these pairwise comparisons are more fully integrated post-MPR. All other pairwise comparisons failed to reject the null hypothesis in equation 1.10 suggesting these markets are fully integrated under the mandatory price reporting system.

Overall the test results suggest that regional fed cattle markets were integrated under the voluntary pricing system, however, additional information was gathered with respect to the magnitude of these relationships after taking into account the potential impact of mandatory price reporting. In the post-MPR environment the strength of market integration increased. This shows that these regional fed cattle markets are more fully integrated with price changes taking place closer to a one-to-one relationship across locations.

### ***Impulse Response Functions***

Impulse response functions were applied to all five regional fed cattle market to identify how prices respond to an exogenous price shock in each market over time. Prices respond to shocks in other variables dynamically and impulse response functions allow us to measure the dynamic adjustment process of prices by incorporating an exogenous price shock on each market one at a time. For example, when an exogenous price shock is imposed on the Texas-Ok market we can then capture the response of all other regional markets along the adjustment path over

time. Impulse response functions allow us to capture two different aspects of price behavior: 1) determine whether an exogenous shock causes prices converge to zero over time or have a permanent effect on the system, and 2) by comparing responses over time we can identify how long it takes for the effect of the shock to leave the system. If mandatory price reporting has increased the availability and reliability on market information then regional market prices should converge to zero more quickly relative to what is observed when public price reporting was voluntary. Convergence to zero indicates the point where the impact of the exogenous shock had dissipated completely and no longer resonates throughout the system. The data was divided between two subsamples that represent the timeframe in which the respective public price reporting system was imposed and comparisons are drawn between them.

Figures 1.1 through 1.5 illustrate the impulse response functions of Texas-Ok, W. Kansas, Colorado, Nebraska, and Iowa-S. Minn. for voluntary price reporting respectively. In figure 1.1 an exogenous price shock to the Texas-Ok market decreased the price in all other regional markets with prices typically converging to zero within two weeks. In figure 1.2 an exogenous shock to the price of the W. Kansas market had little to no influence on the Texas-Ok price with the Colorado, Nebraska, and Iowa-S. Minn. markets taking approximately a week to fully adjust to the impact of the price shock. When an exogenous price shock was imposed on Colorado or Nebraska market prices there was no notable influence on Texas-Ok or W. Kansas prices and the impact of the shock dissipated in about a week in the Iowa-S. Minn. market. Texas-Ok, W. Kansas, Colorado, and Nebraska prices adjusted to the shock to the Iowa-S. Minn. price after about two weeks.

Figures 1.6 through 1.10 show the impulse response function results for Texas-Ok, W. Kansas, Colorado, Nebraska, and Iowa-S. Minn. for mandatory price reporting respectively. The

effect of an exogenous shock to Texas-Ok caused a decrease in the price of all other fed cattle markets and the impact of the price shock completely dissipated within one to two weeks. In contrast to the voluntary system, price adjustments had converged to zero approximately one full week quicker for the same markets under mandatory price reporting. An exogenous shock to the W. Kansas price dissipated after approximately two weeks in all fed cattle markets, roughly one week slower relative to the voluntary system. A shock to the Colorado price showed similar results to those of depicted with the voluntary system.

### ***Forecast Error Variance Decomposition***

Forecast error variance decompositions were used to measure the impact of mandatory price reporting in terms of the amount of volatility that can be explained by price movements across spatial fed cattle markets. Specifically, variance decompositions determine how much of the forecast error variance of each variable can be explained by an exogenous price shock in one of the other variables. Forecasts are made five-weeks ahead to determine how much of the variance is explained across different horizons. A five-week horizon was chosen because the within-sample variance decompositions were relatively unchanged after five weeks. The data was separated into two subsamples that correspond to time period associated with the voluntary and mandatory systems such that inferences can be made between them.

To determine the effect of different shocks on each variable, forecast error variance decompositions were calculated for both the voluntary and mandatory price reporting systems. Forecast errors for the voluntary system are presented in table 1.3. The volatility in all five regional fed cattle markets was mostly explained by the innovations in the Colorado market in the short-run. In the case of the five week ahead forecast for Texas-Ok, about 73.8% of the forecast error is explained by the Colorado market, while approximately 15.1% of the volatility



is explained by innovations in its own market. The five week ahead forecast error for Colorado about 82% of the volatility was explained by the innovation in its own market. Similar results were found in the remaining markets suggesting that Texas-Ok, W. Kansas, Nebraska, and Iowa-S. Minn. markets are dependent upon the Colorado market in the short-run.

Table 1.4 summarizes the results of the forecast error decompositions for the time period following the implementation of mandatory price reporting. The majority of the volatility among each respective market was again explained by innovations in the Colorado market. The five week ahead forecast error for the Texas-Ok about 57% of the volatility was explained by innovations in Colorado, while 33% of the forecast error was explained by innovations in its own market. The five week ahead forecast error for Colorado about 87% of the volatility was explained by the innovation in its own market. From the forecast error decompositions alone it is unclear whether MPR has resulted in an increase in information flow and market transparency. These results may be influenced by other factors such as differences in cattle volume, cattle type, and distances between markets.

### ***Granger Causality***

Granger causality tests were imposed to examine any changes in the price leadership role that may have occurred between regional fed cattle markets from the introduction of mandatory price reporting. Analysis of lead-lag pricing relationships allow us to gain insight into which markets rely on outside forces for information on market conditions and identify which markets provide the primary sources of information. For example, given that the price leadership role shifted under MPR such that markets have become less dependent on each other for market information then this might suggest that access to more current information has been equalized across locations. Comparisons were drawn between public price reporting regimes and the data

was divided into two subsamples in the same manner described with the impulse response function and forecast error variance sections.

Table 1.5 provides information regarding the Granger causality flows between the five weekly regional fed cattle markets. Consider period I (i.e. voluntary price reporting) and the relationship between prices in the Iowa-S. Minn. and W. Kansas markets. The lagged values of the W. Kansas market Granger cause the current values of Iowa-S. Minn. prices. This result implies that prices in W. Kansas have explanatory power for the prices in the Iowa-S. Minn. market because prices in W. Kansas Granger cause prices in Iowa-S. Minn.; the W. Kansas market is said to act as a price leader and therefore considered a dominant market to the Iowa-S. Minn. market. Conversely, Iowa-S. Minn. is identified as a lag (satellite) market to W. Kansas. Texas-Ok. and W. Kansas markets were identified as price leaders to all other markets.

Referring to period II (i.e. mandatory price reporting) of table 1.5; changes in the price leadership role begin to identify themselves. For example, consider the lead-lag price relationship between the lagged values of Texas-Ok. and the current values of W. Kansas. Here the W. Kansas market is identified as a price leader to the Texas-Ok. market. Market prices in Colorado, Nebraska, and Iowa-S. Minn. were found to play a larger price leadership role between the other markets, however, some feedback was present indicating that causality maybe bi-directional. If prices are more widely visible and represent market conditions with greater accuracy, then prices in neighboring regional markets should be able to respond to price movements more efficiently and effectively. This result suggests an increase in the interaction between markets following mandatory price reporting with more markets sharing the price leadership role and does provide evidence that mandatory price reporting has been successful in creating greater transparency of market prices.

## **Conclusions**

Bivariate cointegration tests, impulse response functions, forecast error variance decompositions, and Granger causality tests were applied to evaluate the impact of mandatory price reporting on regional fed cattle market prices. The test procedures used in this study analyzed market integration from the perspective of cointegration, price responses and their associated volatilities from an exogenous price shock to the system, and changes in the price leadership role to assess the material impact of mandatory price reporting on fed cattle markets that are spatially separated. Studying the movements of spatial prices will increase our understanding of public price reporting in terms of price discovery, market performance, and how geographic markets are defined.

This study provided an assessment of the behavior of regional fed cattle market prices in an effort to link the effectiveness of mandatory price reporting in influencing market performance and promoting price discovery. Mandatory price reporting was designed to facilitate market transparency and has had a noticeable impact on the pricing relationships discussed within this chapter. The previous literature regarding the transparency of the voluntary reported data and the data reported with MPR has been mixed, where some studies have found little difference between the public reporting systems others have found evidence that MPR has enhanced that transparency prices by increasing level of cointegration following the establishment of MPR. This study evaluated mandatory price reporting by analyzing pricing relationship from several different angles and is the only study to do so with the five largest regional fed cattle markets.

Fed cattle markets were defined by their respective weekly reported prices and found to be integrated without regard to the time period under consideration, however, the strength of integration increased following the enactment of mandatory price reporting. This result implies

that these regional market prices do not diverge from one another in the long-run and follow each other more closely, a result that is consistent with mandatory price reporting increasing the amount of market information. The new information provided by MPR such as contracts, formula sales, and other purchasing arrangements that were not reported under the voluntary system appear relevant to price discovery, a result that is supported by the increase in the level of market integration.

Markets responded to exogenous price shocks quicker with mandatory price reporting with price adjustments occurring approximately a week sooner when compared to time period under voluntary price reporting. This response can be attributed to MPR's attempt to increase information flow by requiring industry participants to report additional information that was not previously reported under voluntary price reporting such as information on contracts, and formula sales. Marketing information has become more easily assessable by allowing markets with relatively less trade volume to have more access to a broader information source.

Granger causality tests were used to determine any changes that may have occurred in the price leadership role following the enactment of mandatory price reporting. The leading price discovery regions when price reporting was voluntary were the Texas-Oklahoma panhandle and Western Kansas with Colorado and Iowa-Southern Minnesota identified as a price leader to Nebraska. However, the price leadership role shifted under the mandatory system where several markets become less dependent on each other for changes in market conditions. The Texas-Oklahoma panhandle and Western Kansas began to share their price leadership role with the remaining regional markets. This result implies that markets have become less reliant on each other for market information after mandatory price reporting and supports the notion that mandatory price reporting has in some way enhanced market transparency.

If we think of market transparency in terms of ease of access to information, reliably, and the ability of the reporting party to maintain a current database then overall mandatory price reporting appears to have been successful in accomplishing its stated objectives. Mandatory price reporting was introduced to improve the transparency and accuracy of price reporting in an increasingly dynamic environment and the results of this study generally support notion that MPR has been successful in achieving its broad objectives. However, an analysis regarding societal value of mandatory price reporting versus the costs of collecting and maintaining a continuous database has largely been avoided and creates a sizeable gap in our literature. Research in this area will add to our understanding of the usefulness and perceived necessity of a mandatory system.

There are several other factors that contribute to price discovery and price behavior across geographic boundaries, such as cattle volume, cattle type, transportation costs, alternative marketing agreements, and declining negotiated cash market transactions which may be influencing the some of these pricing relationships. The impact of mandatory price reporting with the creation of different marketing agreements in the presence of a declining negotiated cash market is a separate issue and should be explored further as contract terms are not currently reported by MPR and therefore do not contribute to price discovery. A significant hurdle exists as privacy concerns will likely impede on the ability of mandatory price reporting to effectively report market conditions if markets continue to increasingly engage in private contract negotiations.

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## Tables

**Table 1.1 Cointegration Test Results of Weekly Fed Cattle Prices, January 1992 through April 2011**

Dependent Market/Independent Market	Engle-Granger Test	Gregory-Hansen Test
Colorado/Texas_Ok.	-9.13*	-9.22*
Colorado/W. Kansas	-11.87*	-12.36*
Colorado/Nebraska	-10.17*	-10.42*
Colorado/Iowa_S. Minn.	-10.59*	-10.70*
Iowa_S. Minn./Texas_Ok.	-8.18*	-8.16*
Iowa_S. Minn./W. Kansas	-8.38*	-8.39*
Iowa_S. Minn./Nebraska	-15.55*	-16.22*
Nebraska/Texas_Ok.	-7.95*	-7.92*
Nebraska/W. Kansas	-8.70*	-8.69*
W. Kansas/Texas_Ok.	-8.61*	-8.59*

Note: Single asterisk (\*) indicates statistical significance at the 1% level.



**Table 1.2 Gregory-Hansen Parameter Estimates and Hypothesis Test Results for Weekly Fed Cattle Prices, January 1992 through April 2011**

<b>Dependent Market/Independent Market</b>	<b>Constant</b>	<b><math>\alpha_1</math> Post-MPR Dummy</b>	<b><math>\alpha_2</math> State Variable</b>	<b><math>\alpha_3</math> Post-MPR Regime</b>	<b><math>H_0: \alpha_2 = 1</math> (p-value)</b>	<b><math>H_0: \alpha_2 + \alpha_3 = 1</math> (p-value)</b>
Colorado/Texas_Ok.	1.4259* (0.0550)	-3.4764* (0.6861)	0.9657* (0.0079)	0.0545* (0.0094)	0.00	0.00
Colorado/W. Kansas	1.4566* (0.5322)	-2.9249* (0.6622)	0.9661* (0.0077)	0.0503* (0.0091)	0.00	0.00
Colorado/Nebraska	-2.2121* (0.4362)	1.2081** (0.5312)	1.0243* (0.0064)	-0.0134*** (0.0073)	0.00	0.00
Colorado/Iowa_S. Minn.	-1.7596* (0.5844)	1.2027*** (0.7119)	1.0209* (0.0086)	-0.0192*** (0.0098)	0.02	0.74
Iowa_S. Minn./Texas_Ok.	4.3633* (0.7319)	-4.5988* (0.9131)	0.9279* (0.0106)	0.0753* (0.0125)	0.00	0.63
Iowa_S. Minn./W. Kansas	4.3849* (0.6826)	-4.2129* (0.8493)	0.9285* (0.0099)	0.0731* (0.0058)	0.00	0.79
Iowa_S. Minn./Nebraska	0.0172 (0.3891)	0.2301 (0.4737)	0.9967* (0.0057)	0.0042 (0.0065)	0.56	0.80
Nebraska/Texas_Ok.	4.3448* (0.6066)	-4.9271* (0.7568)	0.9312* (0.0088)	0.0723* (0.0103)	0.00	0.52
Nebraska/W. Kansas	4.3095* (0.5962)	-4.2705* (0.7419)	0.9326* (0.0086)	0.0667* (0.0098)	0.00	0.90
W. Kansas/Texas_Ok.	0.0729 (0.3385)	-0.3721 (0.4223)	0.9980* (0.0049)	0.0023 (0.0058)	0.68	0.93

Note: Single, double, and triple asterisks (\*) indicate statistical significance at the 1%, 5%, and 10% levels, respectfully.

**Table 1.3 FEVD for Weekly Fed Cattle Prices, January 1992 through April 2001**

Horizon1	Variance Decomposition for Texas Ok					Variance Decomposition for W. Kansas				
	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.
1	0.1427	0.0000	0.7972	0.0586	0.0015	0.1016	0.0322	0.8045	0.0606	0.0011
2	0.1398	0.0005	0.7881	0.0626	0.0089	0.1009	0.0475	0.7822	0.0623	0.0071
3	0.1458	0.0165	0.7641	0.0618	0.0103	0.1068	0.0624	0.7607	0.0621	0.0081
4	0.1436	0.0314	0.7512	0.0634	0.0104	0.1055	0.0767	0.7469	0.0624	0.0088
5	0.1513	0.0305	0.7378	0.0613	0.0192	0.1111	0.0745	0.7348	0.0598	0.0197
Horizon	Variance Decomposition for Colorado					Variance Decomposition for Nebraska				
	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.
1	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.8053	0.1947	0.0000
2	0.0559	0.0001	0.8607	0.0745	0.0088	0.0446	0.0011	0.7540	0.1777	0.0226
3	0.0634	0.0116	0.8418	0.0733	0.0099	0.0516	0.0188	0.7311	0.1738	0.0249
4	0.0670	0.0168	0.8304	0.0734	0.0125	0.0535	0.0259	0.7224	0.1724	0.0258
5	0.0701	0.0164	0.8191	0.0718	0.0197	0.0163	0.0249	0.7109	0.1656	0.0373
Horizon	Variance Decomposition for Iowa_S. Minn.									
	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.					
1	0.0000	0.0000	0.7466	0.1631	0.0903					
2	0.0451	0.0041	0.7100	0.1559	0.0859					
3	0.0478	0.0221	0.6904	0.1518	0.0792					
4	0.0488	0.0272	0.6835	0.1536	0.0870					
5	0.0594	0.0271	0.6764	0.1482	0.0886					

**Table 1.4 FEVD for Weekly Fed Cattle Prices, April 2001 through April 2011**

Horizon	Variance Decomposition for Texas Ok					Variance Decomposition for W. Kansas				
	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.
1	0.2781	0.0000	0.6677	0.0536	0.0005	0.0274	0.1304	0.7818	0.5558	0.0046
2	0.2715	0.0099	0.6549	0.0522	0.0115	0.0267	0.1276	0.7816	0.0545	0.0096
3	0.2751	0.0215	0.6409	0.0502	0.0123	0.0413	0.1426	0.7534	0.0519	0.0109
4	0.2747	0.0245	0.6329	0.0558	0.0121	0.0411	0.1434	0.7462	0.0583	0.0110
5	0.2708	0.0250	0.6355	0.0568	0.0120	0.0442	0.1403	0.7410	0.0614	0.0131
Horizon	Variance Decomposition for Colorado					Variance Decomposition for Nebraska				
	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.	Texas_ Ok	W. Kansas	Colorado	Nebraska	Iowa_S. Minn.
1	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.8161	0.1839	0.0000
2	0.0046	0.0294	0.9228	0.0248	0.0184	0.0039	0.0256	0.7690	0.1693	0.0323
3	0.0119	0.0444	0.9000	0.0239	0.0197	0.0151	0.0364	0.7540	0.1632	0.0314
4	0.0135	0.0464	0.8887	0.0318	0.0196	0.0152	0.0435	0.7443	0.1663	0.0307
5	0.0170	0.0447	0.8799	0.0363	0.0221	0.0190	0.0420	0.7392	0.1658	0.0340
Horizon	Variance Decomposition for Iowa S. Minn.									
	Texas Ok	W. Kansas	Colorado	Nebraska	Iowa S. Minn.					
1	0.0000	0.0000	0.7356	0.1486	0.1158					
2	0.0030	0.0211	0.7286	0.1384	0.1089					
3	0.0095	0.0339	0.7139	0.1371	0.1055					
4	0.0115	0.0413	0.7032	0.1406	0.1034					
5	0.0155	0.0398	0.7030	0.1402	0.1014					

**Table 1.5 Summary F-Statistics for Casual Flows between Weekly Fed Cattle Prices, January 1992 through April 2011**

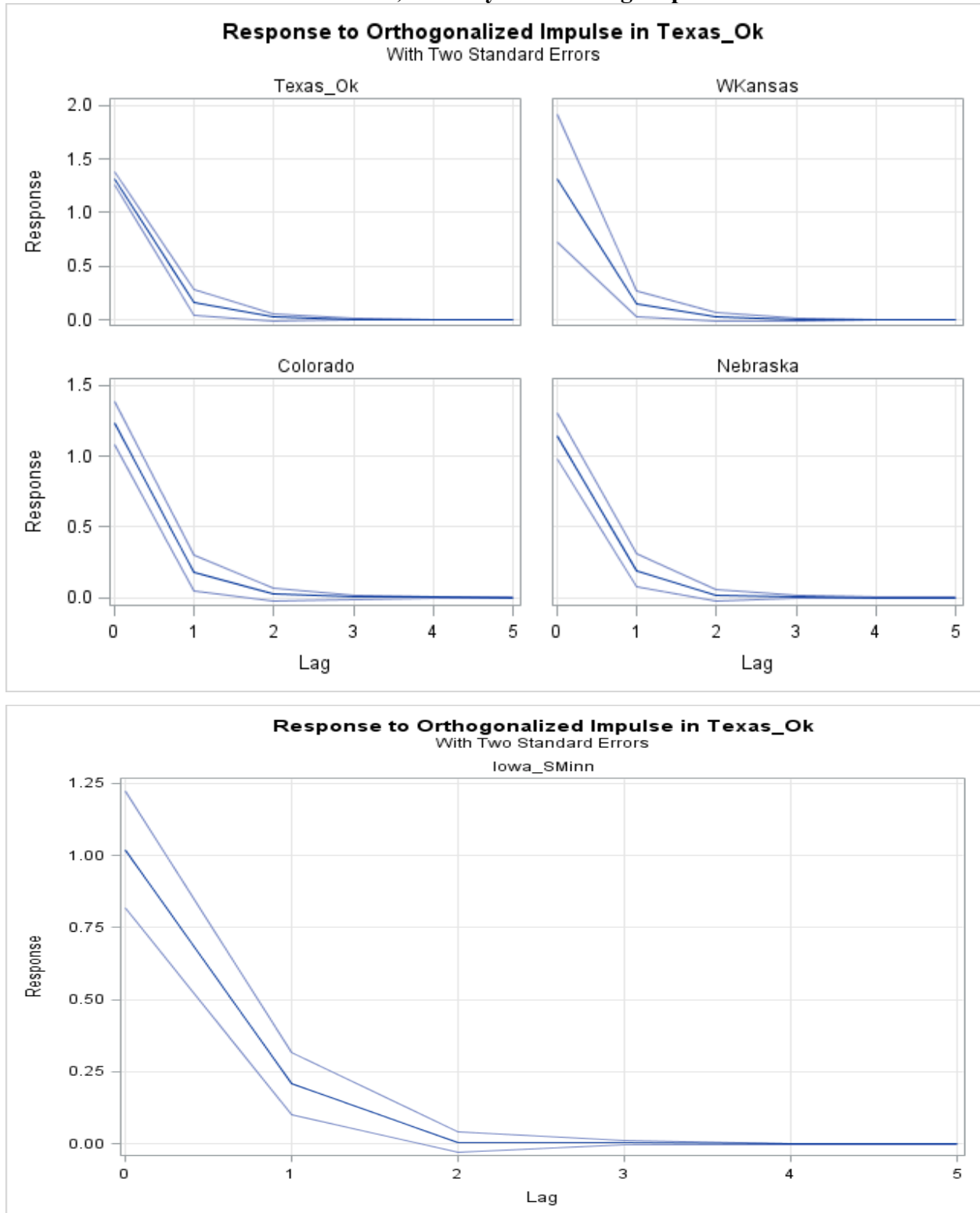
<b>Lagged Independent Market</b>						
<b>Dependent Market</b>	<b>Time Period<sup>a</sup></b>	<b>Texas_Ok</b>	<b>W. Kansas</b>	<b>Colorado</b>	<b>Nebraska</b>	<b>Iowa_S. Minn.</b>
<b>Texas_Ok</b>	I	6.63*	1.39	0.06	0.04	0.84
	II	2.49	19.51*	3.42**	6.61*	11.28*
<b>W. Kansas</b>	I	1.60	4.63*	0.13	0.05	0.95
	II	0.92	0.28	17.64*	14.27*	5.22*
<b>Colorado</b>	I	35.52*	34.13*	0.19	15.29*	20.39*
	II	16.32*	21.33*	2.11	1.89	11.28*
<b>Nebraska</b>	I	24.22*	24.14*	4.03**	0.91	11.12*
	II	5.96*	17.10*	1.86	1.47	7.80*
<b>Iowa_S. Minn.</b>	I	14.44*	14.41*	0.74	1.22	4.62*
	II	8.16*	7.38*	0.15	0.14	0.59

Note: Single and double asterisk denote statistical significance at the 1% and 5% levels, respectively.

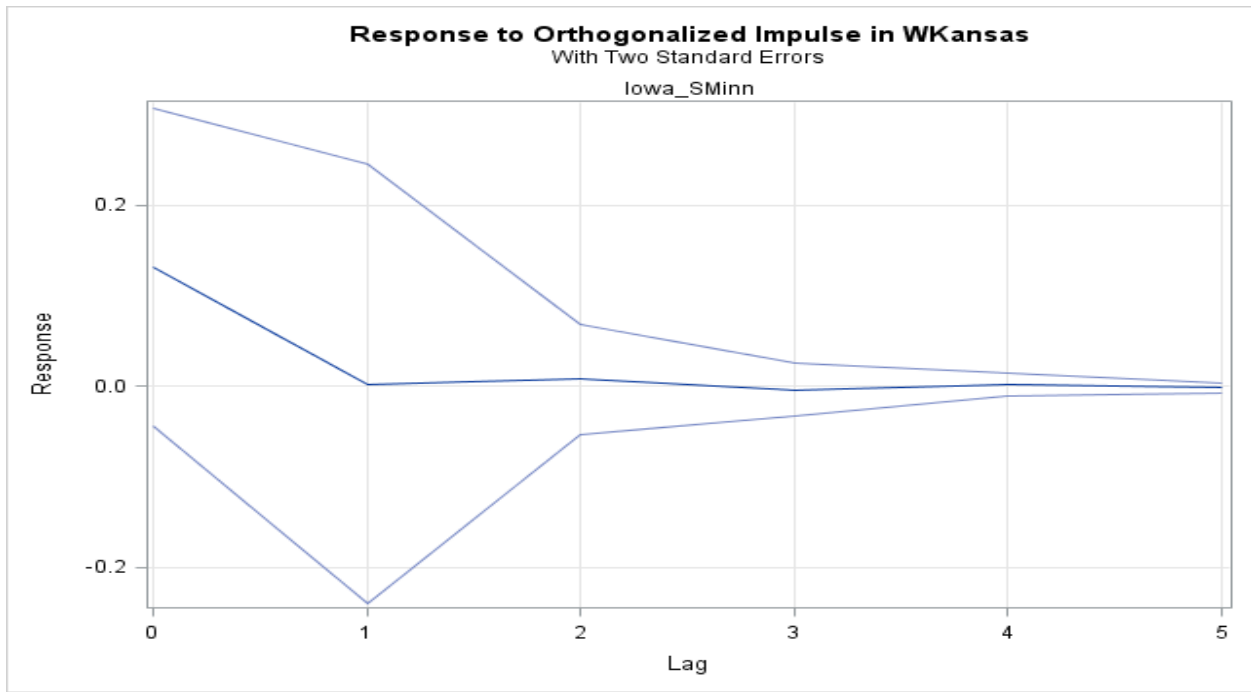
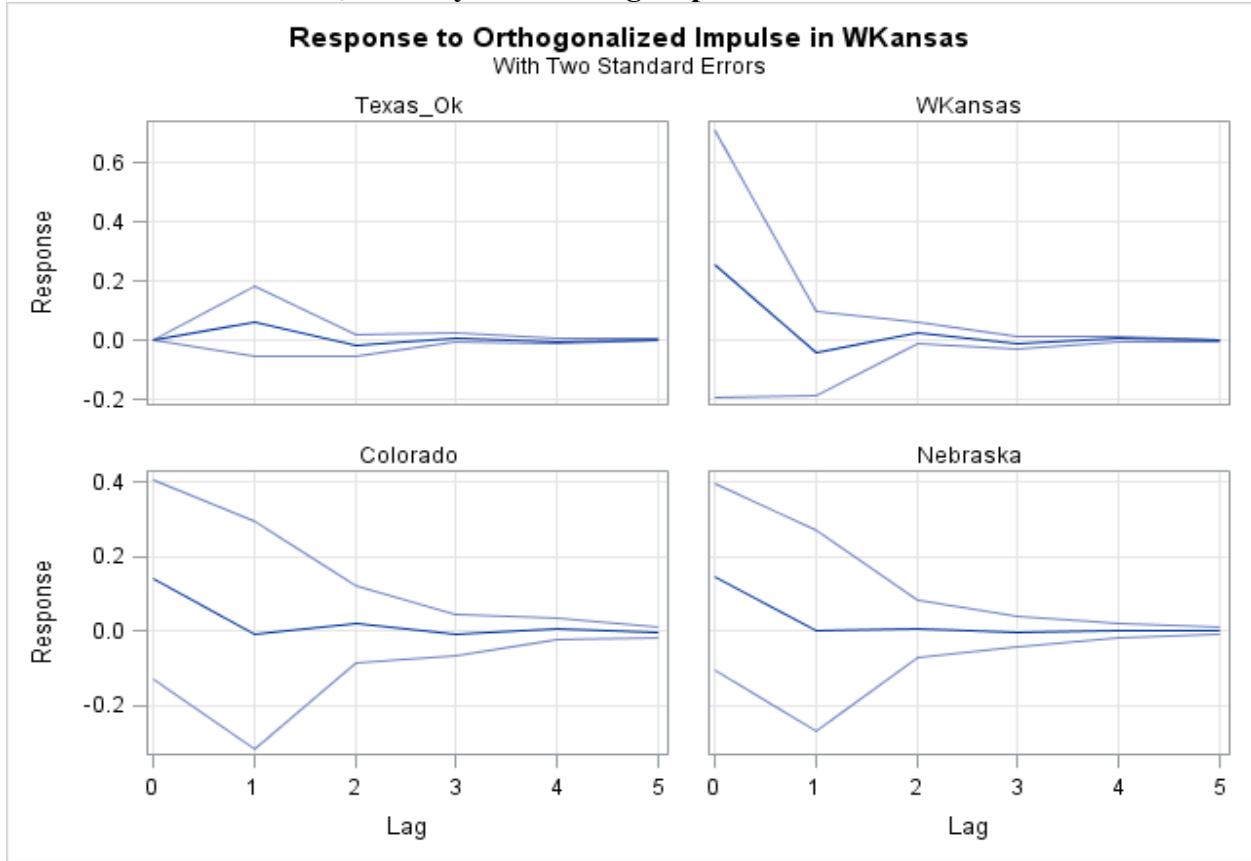
<sup>a</sup>Roman Numerals denote time periods: (I) is January 1992 through April 2001 (voluntary price reporting), (II) April 2001 through April 2011 (mandatory price reporting).

## Figures

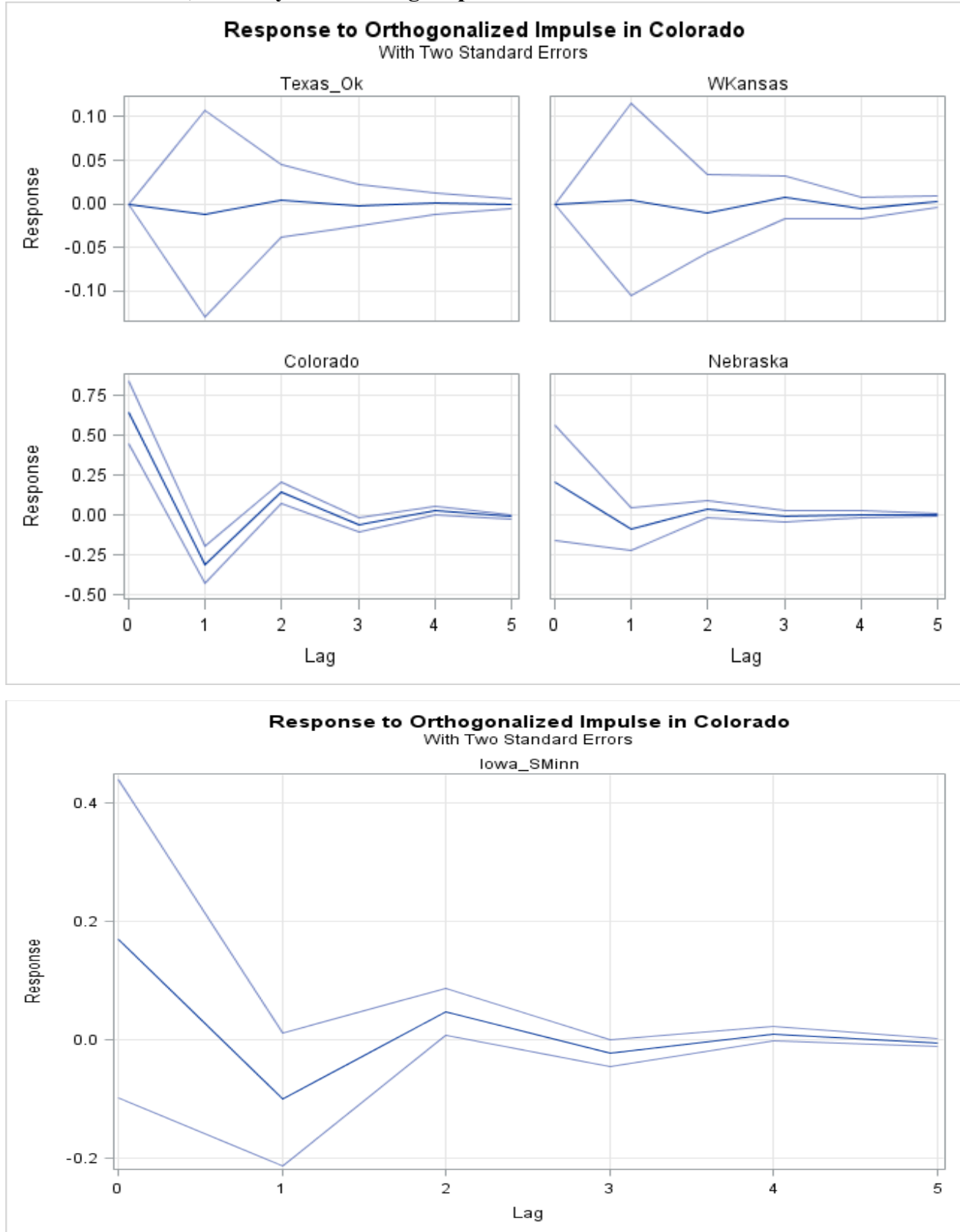
**Figure 1.1 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Texas-Oklahoma Panhandle Market, January 1992 through April 2001**



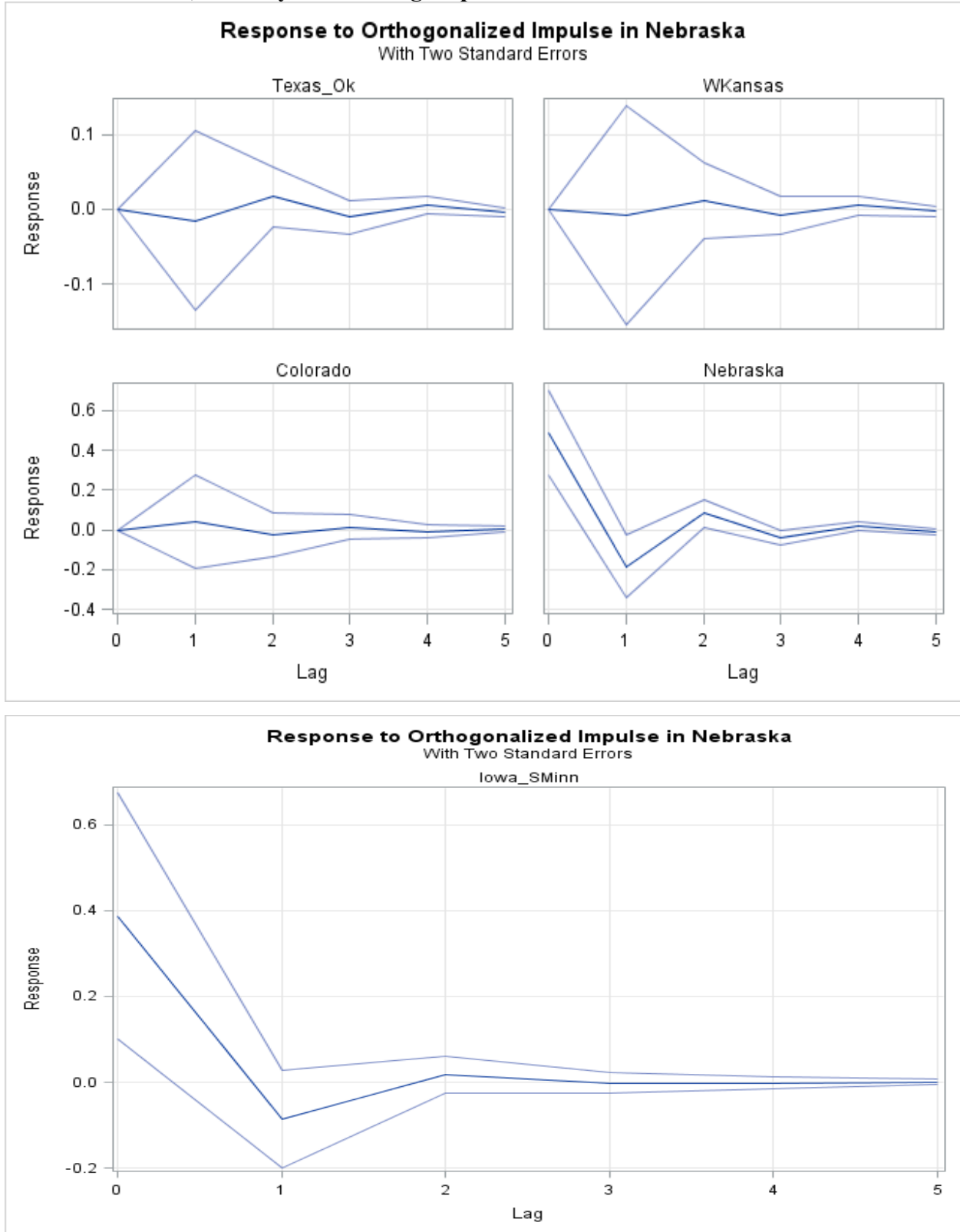
**Figure 1.2 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Western Kansas Market, January 1992 through April 2001**



**Figure 1.3 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Colorado Market, January 1992 through April 2001**

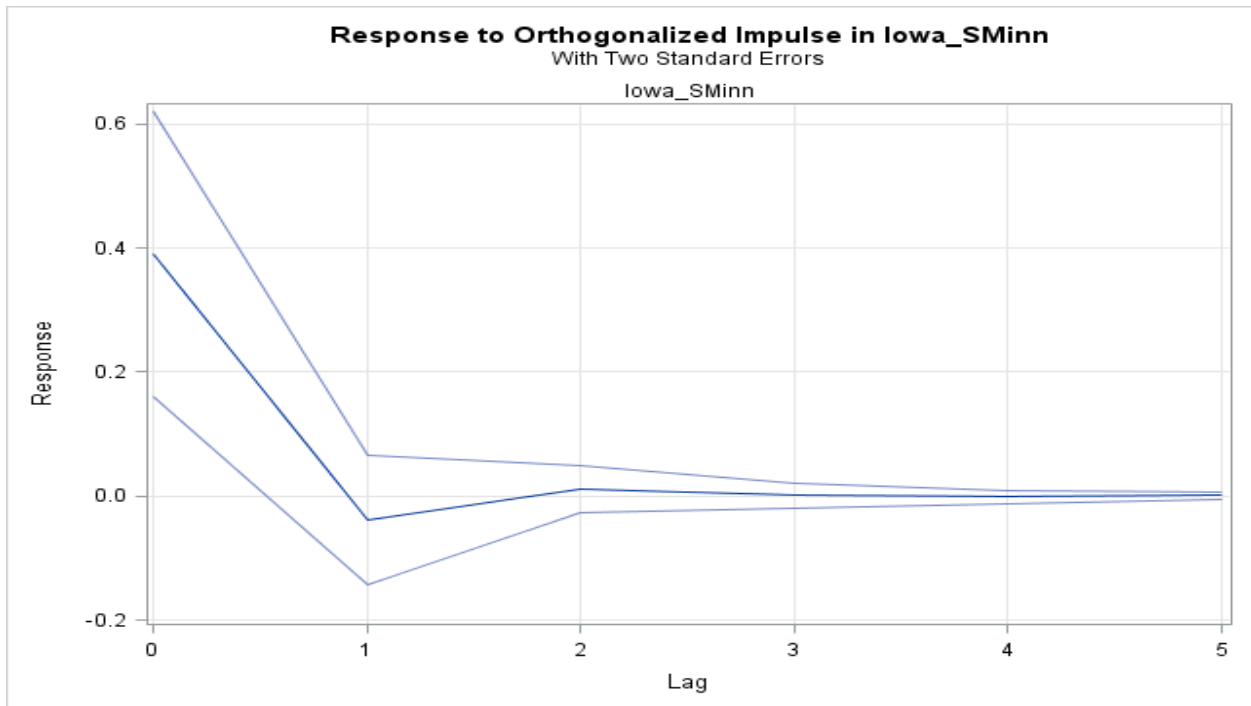
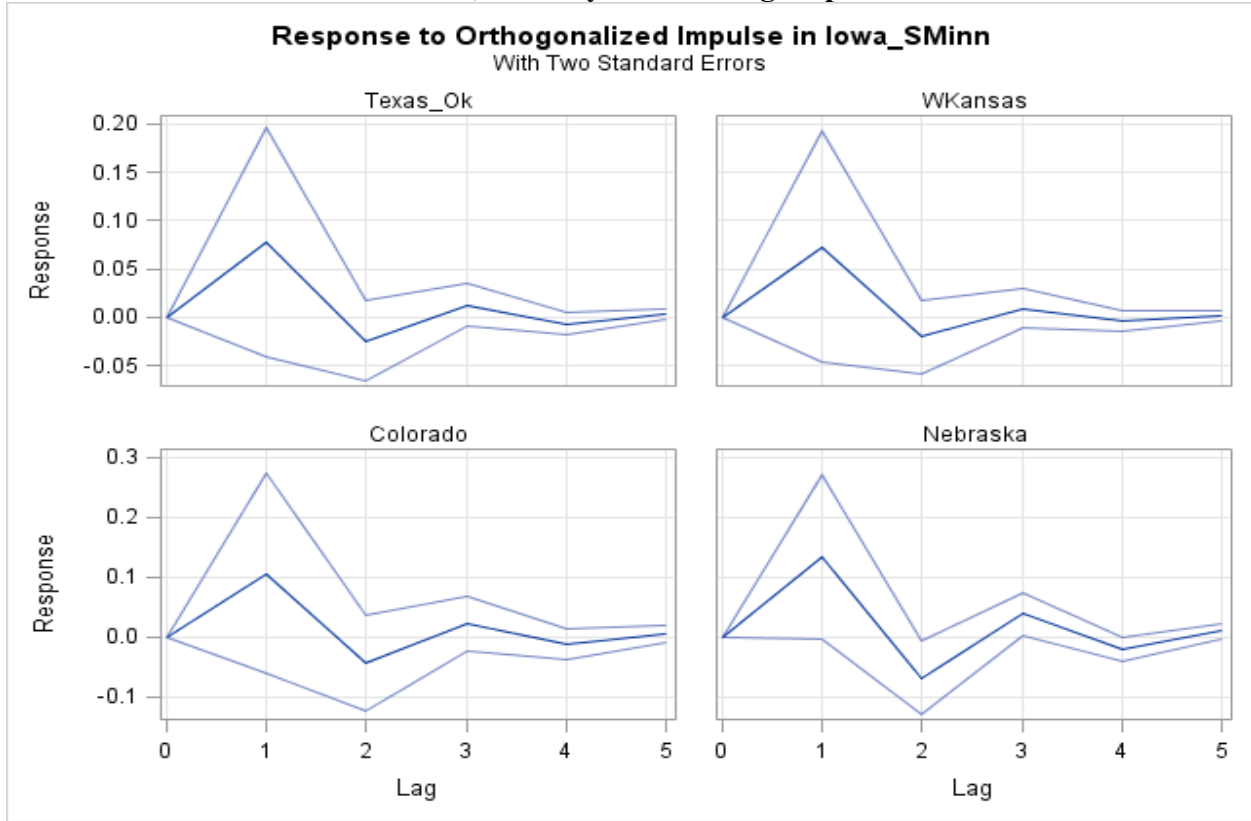


**Figure 1.4 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Nebraska Market, January 1992 through April 2001**

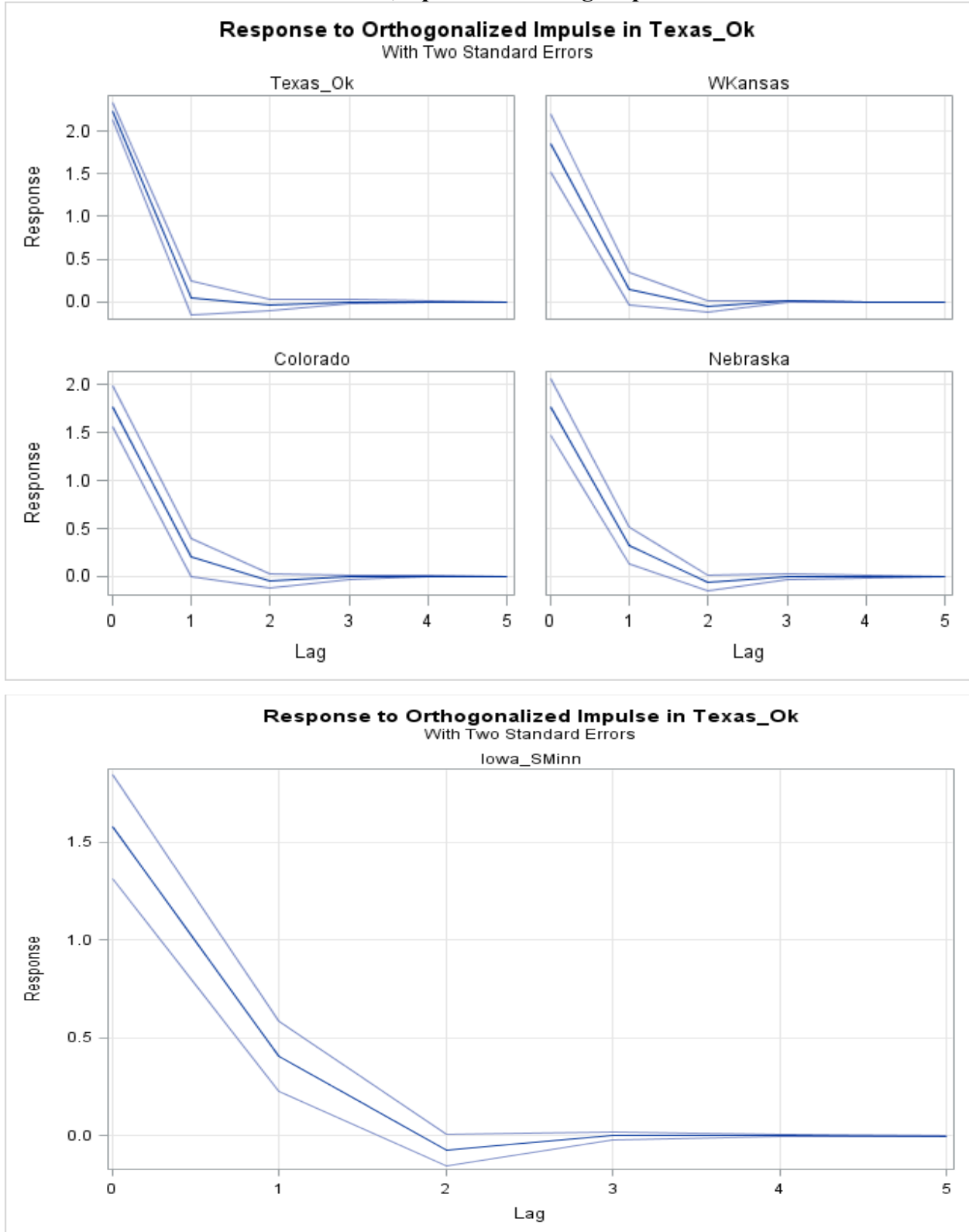




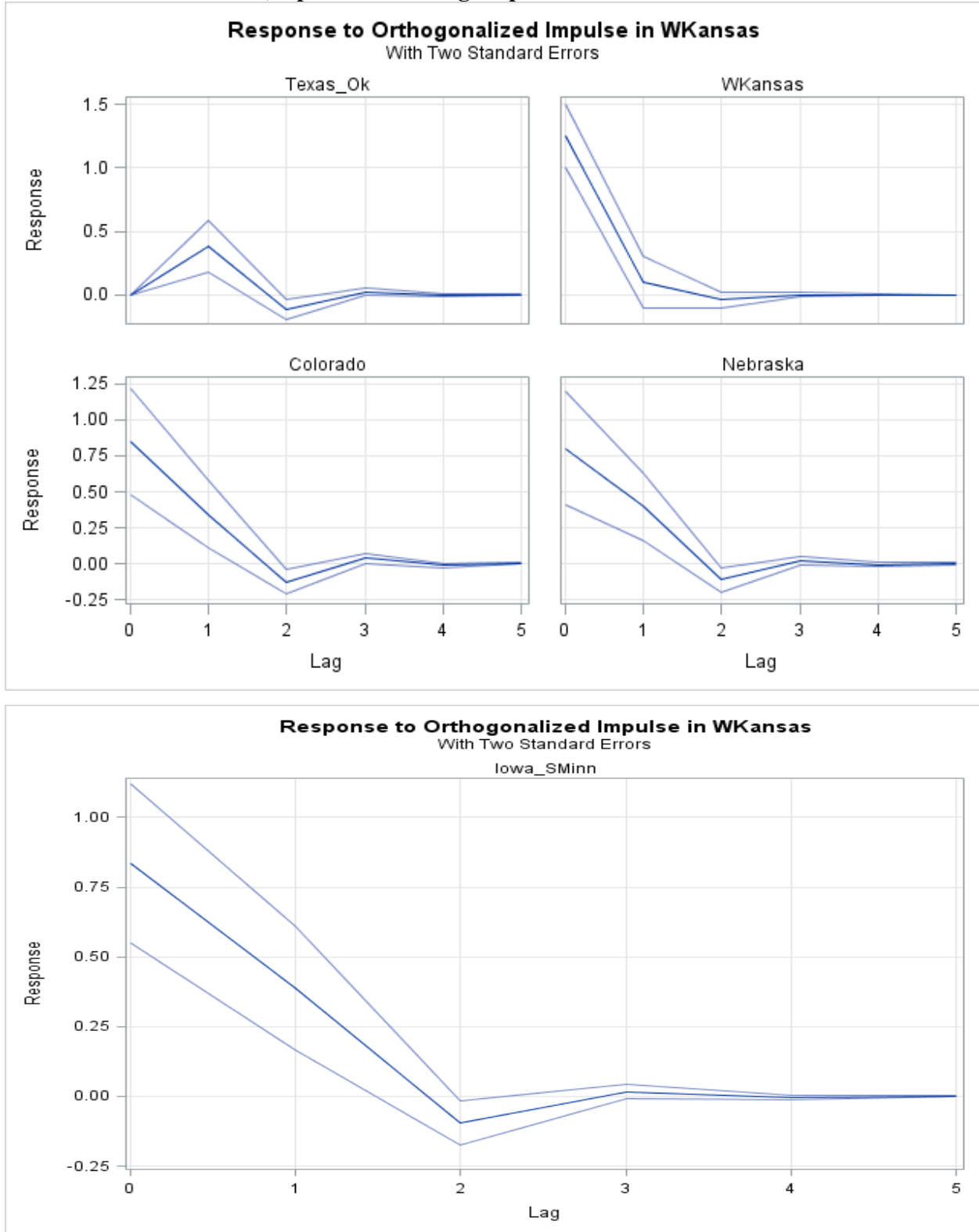
**Figure 1.5 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Iowa-Southern Minnesota Market, January 1992 through April 2001**



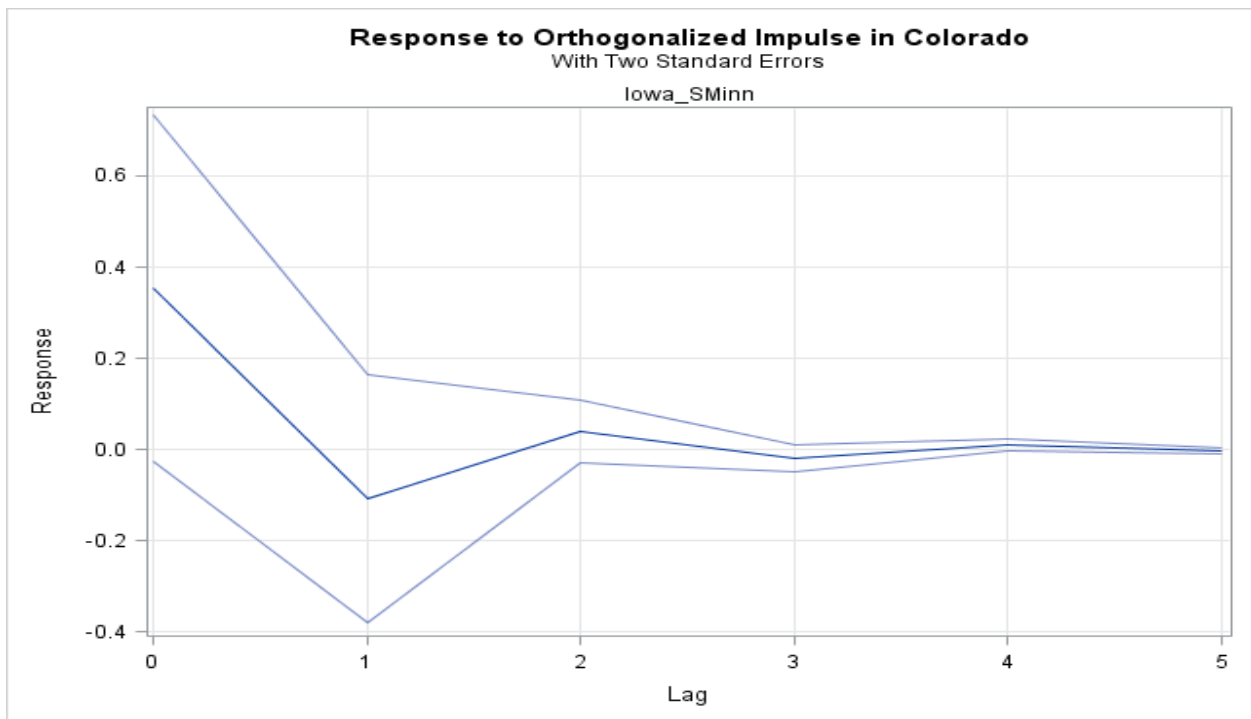
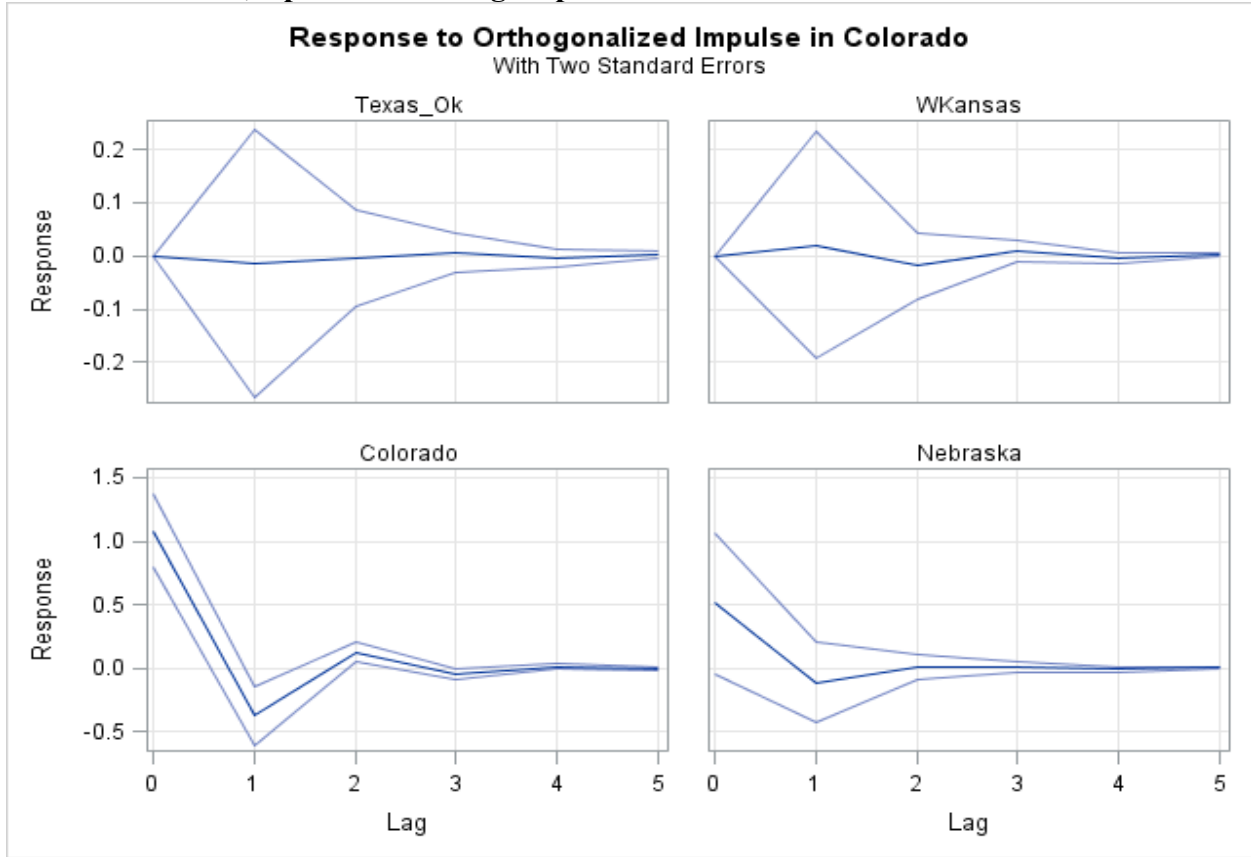
**Figure 1.6 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Texas-Oklahoma Panhandle Market, April 2001 through April 2011**



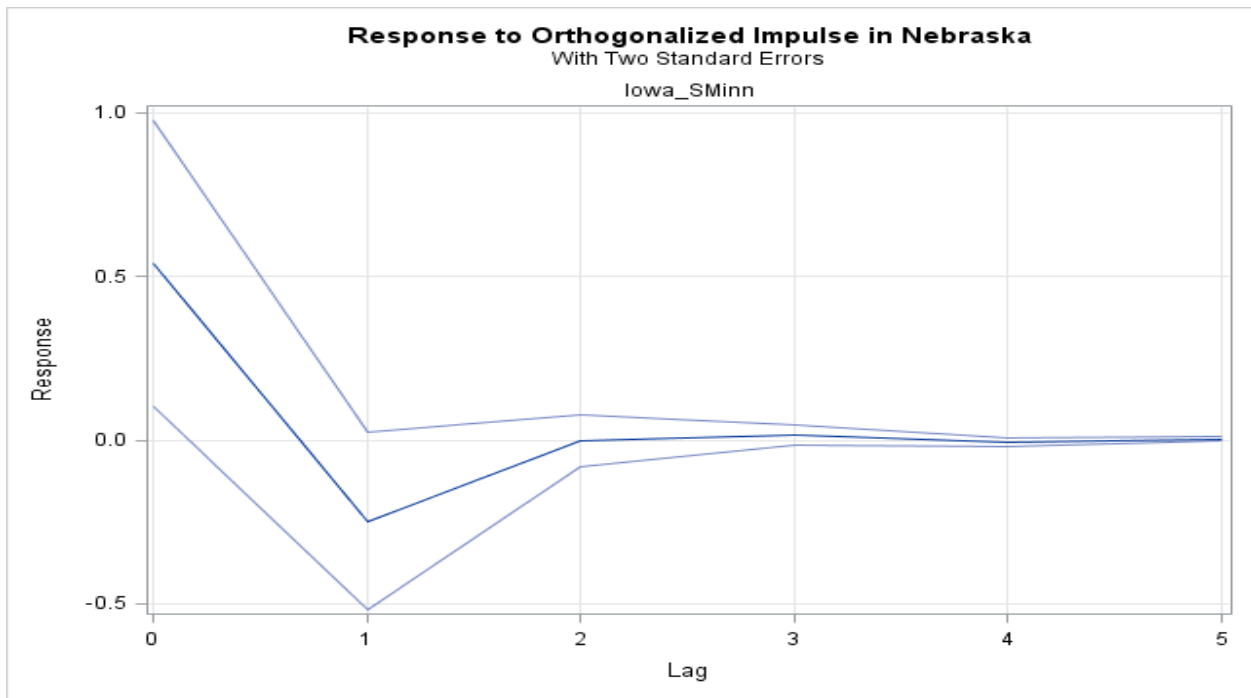
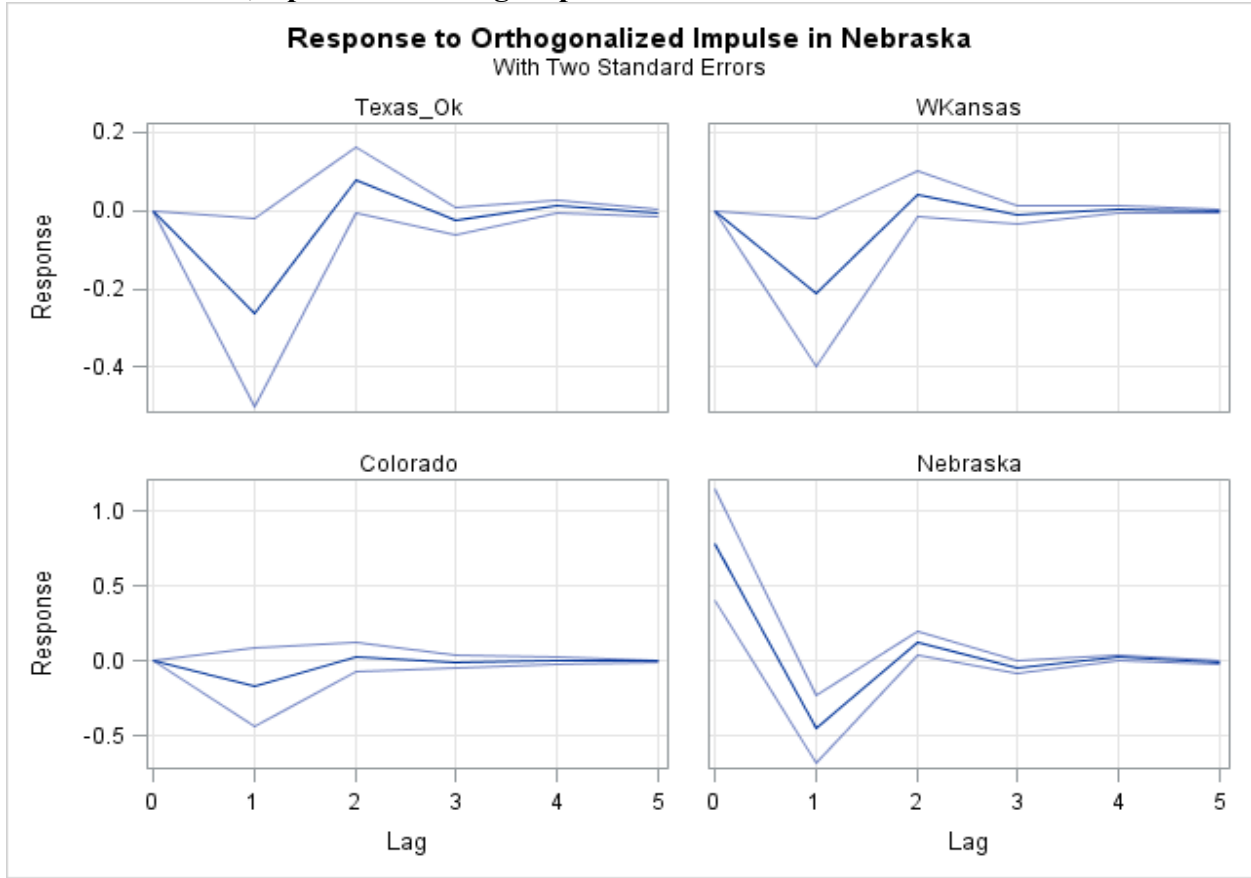
**Figure 1.7 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Western Kansas Market, April 2001 through April 2011**



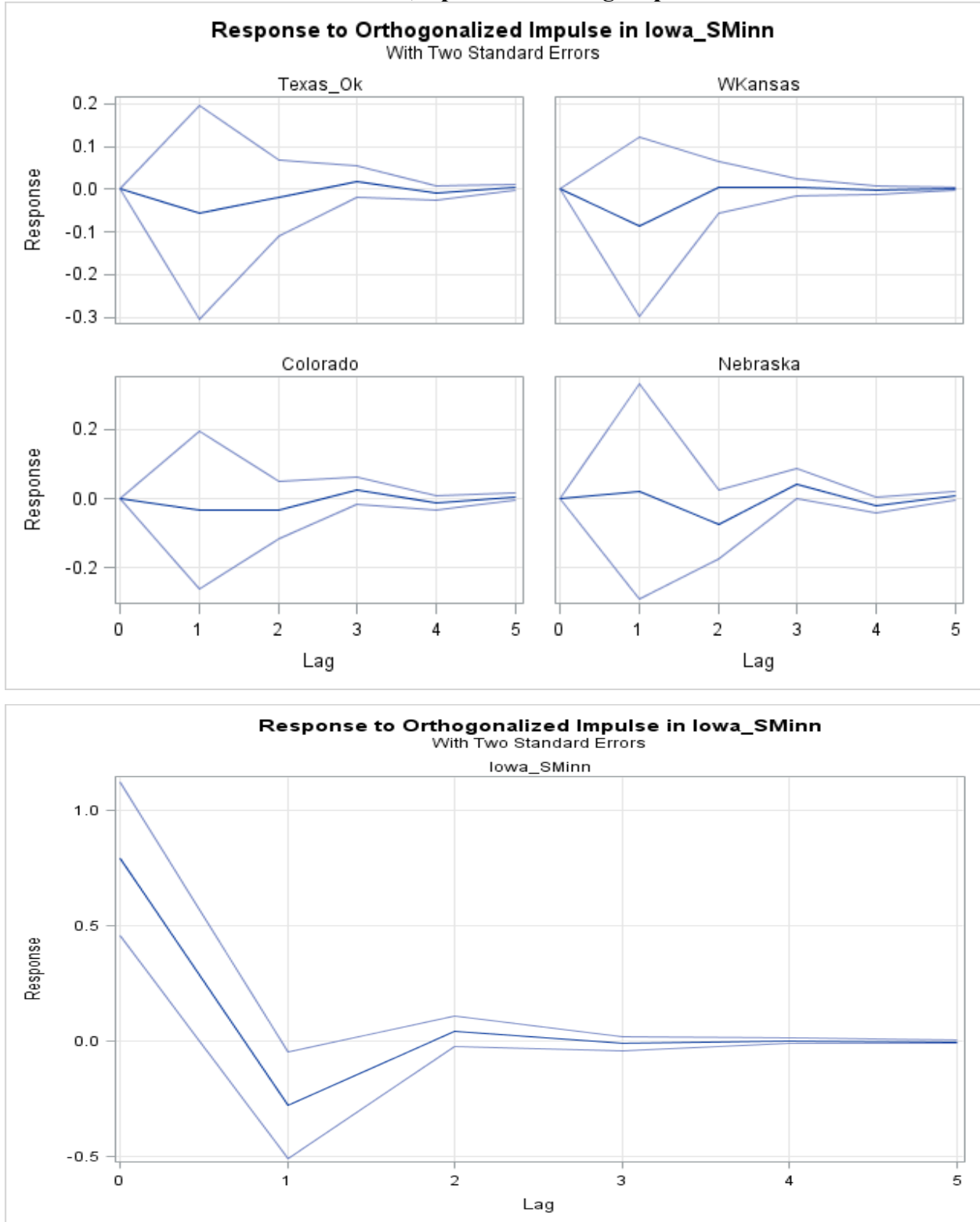
**Figure 1.8 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Colorado Market, April 2001 through April 2011**



**Figure 1.9 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Nebraska Market, April 2001 through April 2011**



**Figure 1.10 Price Responses of Weekly Fed Cattle Markets with Two Standard Errors in the Iowa-Southern Minnesota Market, April 2001 through April 2011**



## **Chapter 2 - Measuring Profit Variability in Fed Cattle Production**

### **Introduction**

The United States cattle feeding industry operates in an environment layered with both production and market risk causing profits to fluctuate over time. For example, during 2011 the net return to Kansas cattle feeding ranged from more the \$170 per head profit for cattle finished in April to losses exceeding \$100 per head for cattle harvested just two months later in June (Langemeier 2011). The variability in profits originates from variability in prices of both inputs and output and the production performance of animals. Variability in prices and production lead to fluctuations in cattle feeding profit causing the cattle feeder to seek out more effective risk management strategies. Quantifying production and market risk is essential to the development of risk management strategies. Price risk is associated with changes in feed costs as well as fed and feeder cattle prices, whereas yield risk is a function of cattle health, production technology, and weather as well as innate animal feeding performance capability (Belasco et al. 2009). Understanding how price and yield risks are characterized gives cattle feeders' insights into the determinants of profit and profit risk.

This research follows a model of fed cattle profit risks similar to that presented in Belasco et al. (2009) where, given the information available at placement, models are derived and estimated to capture profit variability, ex-ante, for a pen of cattle given conditioning factors present at the time. Prior research has been widely focused on identifying cattle feeding risk determinants on the aggregate over the long-run. This study is different than prior research in that it focuses on the behavior of cattle feeder profits variability (ex-ante) given the information available at placement.

Belasco et al. (2009) is the only study that has taken an ex-ante approach to assess the variability in cattle feeding profits. The modeling procedure employed here is designed to account for conditioning variables that are known to the cattle feeder at the time cattle are placed on feed, but are deterministic in nature which allows for robustness assessment of cattle feeding profits. More importantly, the data set used in this study is about twice as large and more recent, providing a richer outlook in the underlying behavior of cattle feeding profits. Also, the addition of interaction terms in the model presents an opportunity to capture information that has not been identified in other studies. The use of interaction terms shows how several production performance measures are conditional (e.g. cattle feeding performance risk varies seasonally for light-weight compared to heavy-weight placement). This analysis adds to our understanding of why cattle feeding profits vary so dramatically and in the information gleaned helps us advise cattle feeders in developing more effective risk management strategies.

## **Literature Review**

Langemeier, Schroeder, and Mintert (1992) analyzed the impact of prices and animal performance on finishing cattle profits per head using closeout data. Movements in fed cattle price explained approximately 50% of the variability in cattle feeding profit, 25% was explained by feeder cattle price, and about 22% was contributed by changes in corn prices. Variability in profit was influenced by the average price of feed for lighter-weight cattle whereas cattle feeder profit for heavier-weight placed cattle were more affected by costs of the feeder and daily gain.

Schroeder et al. (1993) used closeout data to examine the relative impacts of prices and cattle performance on cattle feeding profits for various placement weights. Producers with lighter-weight cattle need to be more aware of fed cattle sale prices and feed grain prices than



producers with heavier cattle. Lighter weight cattle are inherently on feed longer than heavier cattle providing a greater lag between placement and ending cattle harvest prices.

Lawrence, Wang, and Loy (1999) examined various factors affecting cattle feeding profitability in upper Midwestern feedlots. Input and output prices, animal performance, gender, and placement weight, facility design, and placement season all impacted cattle feeding profit. Fed cattle prices and feeder cattle prices explained the majority of profit. All else equal, steers were more profitable than heifers and profits declined as placement weight increased.

Mark, Schroeder, and Jones (2000) investigated variability of cattle feeding profits using closeout data in two Kansas commercial feedlots. They determined the relative impacts of fed and feeder cattle prices, feed costs, and animal performance on the variability of cattle feeding profit. Cattle feeders should focus on managing price risk for both fed and feeder cattle because those prices have a greater impact on profitability compared to the price of corn (feed price), interest rates, and animal performance. Factors such as placement weight were more strongly correlated with feeder cattle prices than corn prices, interest rates, and animal performance. As placement weight increases, feeder cattle prices were shown to have a greater influence on profitability relative to the price of corn, interest rates, and animal performance factors.

Mark and Schroeder (2002) analyzed the effects of weather conditions on average daily gain and profitability for feeder cattle located in Western Kansas commercial feedlots. Weather affects average daily gain and profit differently based on cattle gender, placement weight, and placement month. Cattle feeding performance was optimal between 40-60<sup>0</sup>F on average. As temperatures move above this range, feed consumption declines in hotter temperatures and when temperatures move below, maintenance energy increases.

Belasco et al. (2009) measured yield and profit risk associated with cattle feeding using closeout data across feedlots located in Kansas and Nebraska. Using a mean-variance approach the conditional mean and conditional variance of yield factors were affected by gender, placement weight, placement location, and placement season. Fed cattle prices had a strong influence on overall profit variability.

This study analyzes individual risk factors affecting fed cattle profit variability and overall profit variability using closeout data for cattle feedlots in Kansas and Nebraska feedlots. Specific objectives of this study are to: 1) characterize price and yield risks associated with fed cattle production; and 2) estimate fed cattle price and yield factors to gain a better understanding of the distribution of cattle feeding profit determinants. The results provide information regarding the distribution of variability in profit as well as how gender, placement location, placement weight, and placement season influence net returns of the cattle feeder. Two models are estimated in this study. The first model is a base model and is used to identify how well the data performs. The second model extends the base model to include interaction terms to assess the relationship among conditionality factors. Simulations are then performed using the information gained from the base model to determine the distributional characteristics of cattle feeding profits by incorporating price and yield risk factors specific to fed cattle production.

## **Methods and Procedures**

Models are estimated that provide profit estimates (ex-ante) for a particular pen of cattle based upon how cattle are conditioned at the time they are placed on feed. In this context, ex-ante risk is a conditional prediction of risk at a future point known only when cattle are placed on feed. Models are developed to identify the distributional properties of production risk that provide the basis for creating expected profit outcomes for a pen of cattle given various

conditioning characteristics that can be controlled by the cattle feeder. Estimates of fed cattle prices and feed cost together with the information derived from econometric models that assess yield risk determinants serve as the framework for estimating the distributional characteristics of the ex-ante profits of cattle feeders.

Four equations are estimated to measure the overall performance of a given pen of cattle the models are identified by: 1) dry matter feed conversion (DMFC), a measure of the pounds of dry feed required per pound of live weight, 2) mortality rate, 3) veterinary cost per head (VCPH), and 4) average daily weight gain (ADG). The approach measures the distributional properties of cattle production yield factors by specifying variables that affect the conditional mean and variance for cattle feeders. The conditioning variables are those under the control of the cattle feeder and are known at the time cattle are placed on feed. The variables include gender (i.e. pens entirely of steers or pens entirely of heifers), feedlot location, placement weight, and seasonal effects associated with when cattle are placed on feed. These conditioning (deterministic) variables are included in each of the four empirical models for overall performance described above and assume the following general form:

$$y_i = f_i(\text{gender}_i, \text{location}_i, \text{inweight}_i, \text{season}_i) \quad (2.1)$$

where  $y_i$  is the measure of performance,  $\text{gender}_i$  is an indicator variable for steers and heifers,  $\text{location}_i$  is an indicator variable for feedlot location (i.e. Kansas/Nebraska),  $\text{inweight}_i$  is the average weight of an entire pen upon entry,  $\text{season}_i$  is an indicator variable denoting the date cattle are initially placed into pens and subscript  $i$  is the cattle yield measure denoted as either DMFC, Mortality, VCPH, or ADG.

The conditional mean and variance are likely influenced by the conditioning factors that are associated with each yield measure. Thus, heteroskedasticity can be an issue. When heteroskedasticity exists, the least squares estimator is unbiased, consistent, and asymptotically

normal (Greene 2008). However, the least squares estimator is less efficient relative to estimators that adjust for the effect of exogenous variables on the variance. It is essential to accurately estimate the variance with each set of deterministic variables. Allowing the variance to be influenced by the conditioning variable provides an understanding into how specified yield factors lead to changes in risk (Belasco et al. 2009). The presence of heteroskedastic errors was tested by a likelihood ratio test. A restricted model was created where the variability had no influence on the conditioning variables,  $\alpha = 0$  in equation 2.4 and equation 2.5.

Harvey's multiplicative heteroskedasticity model is estimated for each model because it allows for unbiased and efficient estimates of the parameters with independently distributed residuals (Belasco et al. 2009). The general formation of this approach is:

$$y_i = x_i' \beta + u_i \quad (2.2)$$

where  $x_i$  is a  $k$  vector of observations on the exogenous variables,  $\beta$  is a  $k \times 1$  vector of parameters, and  $u_i$  is the independent and normally distributed error term (Harvey 1976). The conditional variance is calculated as:

$$\sigma^2 = e^{z_i' \alpha} \quad (2.3)$$

where  $\alpha$  is a  $p$  vector of parameters for each conditioning variable that weighs each characteristic by its effect of the individual variance term,  $z_i$  is a  $p \times 1$  vector containing all deterministic variables influencing the variance and  $e$  is an exponential operator (Harvey 1976; Belasco et al. 2009).

To estimate the four yield measures Harvey's multiplicative heteroskedasticity model was used with maximum likelihood estimation. DMFC, VCPH, and ADG were estimated using the following log-likelihood function for the normal distribution presented by Harvey (1976):

$$\log L = \frac{n}{2} \log 2\pi - \frac{1}{2} \sum_{i=1}^n z_i' \alpha - \frac{1}{2} \sum_{i=1}^n e^{z_i' \alpha} (y_i - x_i' \beta)^2 \quad (2.4)$$

where all notation is as defined above.

The mortality rate model was estimated differently from the other yield measures as approximately 36 percent of the observations did not experience death loss. Therefore, the Tobit model was applied to the regression equation for mortality assuming multiplicative heteroskedasticity. The Tobit model estimates are both biased and inefficient in the presence of heteroskedasticity (Hurd 1979). Once heteroskedasticity is accounted for, the estimates are unbiased and efficient. Maximum likelihood estimation is used to obtain estimates from Harvey's model for mortality by specifying the log-likelihood function from the Tobit model with multiplicative heteroskedasticity. The log-likelihood function is:

$$\log L = \sum_{\forall d_i > 0} -\frac{1}{2} \left[ \log 2\pi + \ln(\sigma^2) + z_i' \alpha + \frac{(y_i - x_i' \beta)^2}{\sigma^2 e^{(z_i' \alpha)}} \right] + \sum_{\forall d_i = 0} \ln \left[ \phi \left( \frac{-x_i' \beta_i}{\sigma^2 e^{(z_i' \alpha)}} \right) \right] \quad (2.5)$$

where  $\phi$  is the normal CDF and all other notation is as defined above. Harvey's model results in two parts of the likelihood function for observations not within the limit (i.e. observations with a positive death loss) and the associated probabilities for the limited observations (i.e. where zero death loss is observed), respectively.

The conditional mean and conditional variance estimates provide information regarding the different risks cattle feeders face when cattle are initially placed on feed. These estimates are used to calculate the expected means and expected variances for the ex-ante profit function. This approach provides insight to the individual risk factors influencing expected fed cattle profits as well as overall variability in profits.

## **Data**

Proprietary production and cost data were collected for 29,928 pens of cattle from 1989-2008 for four cattle feeders with feeding facilities located in Kansas and Nebraska. Values for each of the four dependent variables are calculated as follows: 1) DMFC is the total dry feed used divided by total weight gained in the pen during the feeding cycle, 2) ADG is the difference

between total weight of an entire pen upon placement and the total weight of an entire pen upon exit divided by the number of head sold, 3) VCPH is the amount spent on veterinary services and medications divided by the number of head sold from the pen, and 4) Mortality is the number of cattle deaths during a feeding period divided by the total number of head initially placed on feed. Indicator variables were used to separate pens by gender (1 if steers 0 if heifers), placement location (1 if KS 0 if NE), and placement date (where summer is the default category). Because of large variances associated with placement weight (i.e. inweight), natural logarithmic values were used for inweight in all four models. The average size of a pen of cattle was 131 head with an average placement weight of 680 pounds per head. The average finishing weight was 1173 pounds per head of cattle for the entire pen. Summary statistics and variable descriptions are presented in table 2.1.

## **Results**

To estimate the four equations above, maximum likelihood estimation (MLE) procedure was used assuming multiplicative heteroskedasticity. The results from the likelihood ratio test strongly support the presence of heteroskedasticity where the variance is influenced by the conditionality factors. The four equations include Dry Matter Feed Conversion (DMFC), Average Daily Gain (ADG), Veterinary Costs per head (VCPH), and Mortality Rate. The dependent variables for DMFC and VCPH were estimated using natural logarithmic values. The distribution of the error terms was positively skewed when regressions were run on the initial values of DMFC and VCPH. Therefore, logarithmic values for DMFC and VCPH are necessary because of the parametric distribution assumption for the disturbance terms required by the MLE. Once deterministic factors are conditioned out, the DMFC and VCPH residuals were more appropriately characterized by a log-normal distribution.

### ***Dry Matter Feed Conversion (DMFC) Model***

The MLE results for the DMFC equation from Harvey's model are shown in table 2.2. Steers have a lower DMFC rate implying steers are 3.6% more efficient at converting feed in to weight gain relative to heifers. Cattle finished in Kansas feedlots are 10% more efficient in feed conversion than those finished in the Nebraska feedlots included in this study. Placement weight corresponds to previous studies that as cattle placement weight increases, the DMFC increases, implying that heavier-weight cattle convert feed to weight gain less efficiently than lighter-weight cattle at placement (See: Belasco et al. 2009, Mark et al. 2000, and Schroeder et al. 1993). A 10% increase in placement weight corresponds with a 1.8% increase in DMFC.

Seasonal characteristics can have a significant impact on cattle feeding performance (Mark and Schroeder 2002). Maintenance energy increases in colder temperatures with declining feed consumption when temperatures are hotter and the optimal temperature generally occurs between 40-60°F. Increased precipitation can also affect cattle performance by increasing the stress level of cattle in muddy pens with wet and matted hair coats. Therefore, increased variability in weather conditions can affect cattle feeding performance.

Parameter estimates for winter and fall were not statistically significantly different from summer (the default). The results for winter and fall are not surprising given temperatures ranges that are usually outside the optimal range in winter and the higher precipitation levels often seen in Kansas and Nebraska during the fall. Spring was significant with a positive coefficient. This implies that a pen of cattle started in the spring, as opposed to summer, experience higher DMFC. That is, cattle placed in the spring months are less efficient at converting feed into weight gain. Spring placements often enter feed yards during March when temperatures can fluctuate greatly for this region which can be detrimental to the animal. These cattle are then finishing in the heat of the late summer (i.e. August-Sept) when harvest ready

animals can be highly stressed by the heat. Belasco et al. (2009) found spring placements have the opposite effect, where cattle placed in the spring months are likely to experience lower DMFC, as opposed to summer. In this case, spring placements would be more efficient at converting feed to weight gain.

The MLE conditional variance results for DMFC are also shown in table 2.3. The heteroskedastic parameter estimates are useful in providing information of the effect of conditioning variables on conditional variance, where the intercept term is interpreted as  $\sigma$  according to equation (2.3) (Belasco et al. 2009). The heteroskedastic parameter estimate for placement weight has a significant and positive correlation with higher variance in DMFC suggesting that heavier-weight cattle experience greater variability in feed conversion rates. That is, for a one percentage point increases in placement weight there is a corresponding 0.36% increase in variance. Heavier-weight cattle are generally on feed for a shorter period of time relative to lighter-weight cattle and are more likely to experience shorter periods of both favorable and unfavorable conditions that do not offset each other, resulting in greater DMFC variation over time. This result is the same as Belasco et al (2009) in sign; however, the magnitude of this effect is different, every one percentage point increase in placement weight resulted in a 0.76% increase in variance indicating that this impact may not be as severe as in previous studies.

Heteroskedastic parameters for placement season show positive and significant differences in individual variability across fall and winter months relative to summer. Cattle placed in pens in fall months are associated with 5% percent more variance than summer. The magnitude of this effect is different than that found by Belasco et al. (2009) where pens placed in the fall were associated with 34% more variance than summer. An increase in seasonal variance



for the fall can be due to weather differences in the winter months. However, the results suggest that this impact is not as great and is likely a result of our data capturing more weather differences by spanning a more recent and longer time horizon.

### ***Average Daily Weight Gain (ADG) Model***

The results from the ADG model are shown in table 2.3. The coefficient for steers suggests that steers gain weight faster than heifers by 0.27 pounds per day. Cattle in Kansas feedlots gain weight slower than cattle placed in Nebraska feedlots by 0.11 pounds per day. ADG and placement weight are statistically significant and positively correlated. This result results from heavier-weight placements being switched to full-feed high energy rations quicker when placed in a feedlot, as opposed to lower energy growing rations associated with lighter-weight placements. Combing this result with the higher feed conversion rate found in the DMFC model for placement weight, implies that heavier placed pens are fed more per day than pens with a lighter placement weight.

Placement dates in winter and spring are statistically different from summer. Winter placements experience greater average daily gains relative to summer by 0.02 pounds per day. Pens placed in spring months gain weight slower than summer placements, implying these animals are typically finishing during the late summer when harvest ready animals are stressed by the heat in this region. Fall placement was not statistically different from summer. All conditioning variables had a statistically significant effect on the conditional variance.

### ***Veterinary Costs per Head (VCPH) Model***

The MLE parameter estimates for VCPH are found in table 2.4. The dependent variable (VCPH) for this model was estimated using natural logarithmic values as in the DMFC model. The conditional mean estimates were statistically significant for all conditioning variables. The

coefficient for steers suggests that VCPH is 17% higher for pens consisting entirely of steers as opposed to those consisting entirely of heifers. The higher VCPH for steers implies poorer overall animal health for steers and is further supported by the higher mortality rate for steers compared to heifers. Veterinary costs are 6.8% lower (per head) in Kansas feedlots than Nebraska feedlots. Several factors contribute to differences in veterinary costs between regions including: number of days cattle are on feed, environmental conditions, and management practices.

The parameter estimate for placement weight was negative and statistically significant implying veterinary costs decrease by 2.8% for a one percent increase in placement weight. The seasonal effects for VCPH suggest that cattle placed during the winter, fall, and spring experience lower veterinary costs than cattle placed during the summer. For example, cattle placed in the fall months experience lower veterinary cost per head by approximately 8% when compared to summer. Belasco et al. (2009) found a 1.2% decrease in veterinary costs for a one percentage point increase in placement weight, while fall was not statistically different from summer placements.

The conditional variance of VCPH is shown by the heteroskedasticity estimates in table 2.4. The coefficient for steers implies a negative impact on the conditional variance relative to heifers. Feedlots in Kansas also had a negative impact on the conditional variance of VCPH when compared to feedlots in Nebraska. Placement weight was positive and statistically significant implying that the conditional variance of VCPH is higher for heavier placed cattle. Placements in winter and spring show a lower conditional variance when compared to summer. Fall placement was not statistically different from summer.

### ***Mortality Rate Model***

The MLE results for Mortality are shown in table 2.5. The parameter estimate for steers is positive and significantly different from heifers, implying that pens consisting of steers are 0.29% more likely to experience death loss than pens consisting entirely of heifers. Belasco et al. (2009) found that 0.15% of steer pens experience a higher mortality rate than heifer pens. The coefficient for KS was positive and significant indicating that pens located in Kansas have a 0.25% higher mortality rate than Nebraska feedlots. Placement weight is negatively correlated with mortality rate, suggesting a one percentage point increase in placement weight is associated with a 0.04% decrease in mortality rate. Placement dates in the winter and spring do not have a statistically significant effect on mortality rate, while a 0.03% decrease in mortality rate was found by Belasco et al. (2009). Fall had a positive and statistically significant impact on the expected mortality rate suggesting cattle placed during the autumn months experience higher mortality rates relative to summer. These results differ from Belasco et al. (2009) in that feedlot location and placement date did not have a statistically significant effect on mortality rate.

The conditioning variables for steers and winter were not statistically significant. The coefficient for KS is negative and statistically significant suggesting the conditional variance of mortality rate is lower for Kansas feedlots relative to Nebraska feedlots. Placement weight was also negative and statistically significant indicating a one percentage point increase in placement weight results in a 1.5% decrease in the conditional variance of mortality rate. The coefficient estimates for spring and fall placement suggests a lower variance as opposed to summer.

### ***Conditionality***

The inclusion of interaction terms in the yield models presents an opportunity to capture information that has not been identified in other studies. Interaction terms were included to test

the hypothesis that the relationship between placement weight on DMFC, ADG, Mortality Rate, and VCPH was different across placement seasons. For example, for cattle placed on feed in the spring, heavier weight cattle tend to have higher feed conversion rates, whereas in the summer, heavier weight cattle tend to have lower feed conversion rates. Significant interaction terms indicate that the effect of placement season on the response variable is different at different values of the placement weight which alters the interpretation of the interacting coefficients. However, to better understand the relationship between the placement weight and placement season the expected value and variances are illustrated for DMFC, ADG, Mortality Rate, and VCPH in figures 2.1 through 2.8.

Figure 2.1 shows the expected value of DMFC on placement weight across placement seasons. Lighter weight cattle (less than approximately 750lbs) placed on feed in the fall and winter months have lower feed conversion rates relative to those placed in the spring and summer. Whereas heavier weight cattle (greater than approximately 750lbs) the feed conversion rate begins to transition in toward more favorable spring and summer placements. However, when the variance is considered, figure 2.2, we see that spring placements have the lowest variance, which corresponds to the weather conditions that are more favorable within the feedlot locations. The variance for the relationship between fall placement and placement weight was not found to be statistically different from summer placements and placement weight.

The expected value for the conditionality factors indicate that the relationship between winter, fall, and spring placement seasons and placement weight on mortality rate were not found to be statistically different from cattle placed in summer for corresponding placement weights and illustrated in figure 2.3. However, cattle weighing below 800lb tend to have higher mortality rates regardless of the placement season and a decreasing rate thereafter. This is because lighter

weight cattle spend more time on feed than heavier cattle and therefore more exposed to weather and pen conditions, health risks, etc. The interaction between fall placement and placement weight was statistically different from the interaction between summer placement and placement weight. The variances for mortality rate are plotted in figure 2.4. As placement weight increases the mortality rate declines across seasons suggesting that as cattle become heavier and move closer to sale the death loss of a pen of cattle diminishes.

The expected value and variance of veterinary cost per head are shown in figure 2.5 and figure 2.6 respectively. Figure 2.5 depicts a declining trend in veterinary costs as placement weight increases across placement seasons. That is, when placement weights increase veterinary costs per head decrease regardless the time cattle are initially placed on feed. Cattle weighting approximately 575lbs showed no distinguishable difference between placement weight and placement season on veterinary costs per head. The relationship between placement weight and fall, winter, and spring were statistically different from summer. As placement weight increases (above 575lbs) we find that a lower per head veterinary costs for cattle placed in the fall, winter, and spring relative to summer placements.

The conditionality factors affecting the expected value of average daily gain indicate that the relationship between winter, fall, and spring placement seasons and placement weight were statistically different from cattle placed in summer, figure 2.7. Lighter-weight cattle placed on feed during the winter and fall months experience higher average daily weight gain than cattle place in the spring and summer. However, as cattle become heavier cattle placed in the fall and winter experience a lower average weight gain than identical cattle place in the spring and summer. The variance is shown in figure 2.8. Spring placements have a smaller variance for heavier weight cattle implying great stability in managing animal growth. This result is in line

with the preferred placement season identified in previous studies whether animal performance is determined by the more favorable weather conditions for Kansas and Nebraska feedlots.

### **Profit Simulations**

Profit risk is characterized by combining the predicted values from the four yield measures with the expected means and variances of feed prices and the price of the finished commodity into a profit function for a representative cattle feeder. Analyzing profit risk offers an opportunity to assess the overall distribution of cattle feeding profits as well as the volatility of prices and the individual yield factors associated with cattle feeding performance. Price risk is characterized by the feed price and the price of the finished commodity represented by the expected futures prices for corn and fed cattle, respectively. A covariance matrix is then constructed from the yield risk and price risk factors previously described. The cross-equation correlation coefficients implied by the estimation sample are assumed constant and the off-diagonal covariance terms are changed in the simulations as the conditional variance terms change such that the correlation coefficients are held constant (Belasco et al. 2009).

The distributional properties of expected profits for the cattle feeder was characterized a method by Fackler (1991). The approach takes stochastic draws from a normal distribution while maintaining the correlation structure from the estimated models. The simulated values for prices and yields are assumed unique to their respective conditioning variables and time; the values for mortality are truncated at zero in accordance with the censored definition of the variable. The simulations assume a constant covariance between corn and fed cattle prices to specify the profit function. Profit risk is modeled similarly to Belasco et al. (2009) where revenue and costs of ex-ante profits are specific to the individual cattle feeder. Each simulation is based on the following profit function:

$$\pi = TR - FeedPurC - YrdC - FC - VC - IC \quad (2.6)$$

where  $TR$  is the total revenue of the cattle feeder defined by:

$$TR = FedP * SW * (1 - Mortality) * 0.96 \quad (2.7)$$

$FedP$  is the price per hundred weight (\$/cwt.) of fed cattle and  $SW$  is the average sale weight of fed cattle equal to:

$$SW = PW + (ADG * DOF) \quad (2.8)$$

$PW$  is the average placement weight of feeder cattle and  $DOF$  is the number of days cattle are placed on feed.

$FeedPurC$  is the per head purchasing cost of feeder cattle defined as:

$$FeedPurC = PFC * PW \quad (2.9)$$

$PFC$  is the price per hundred weight of feeder cattle.

$YrdC$  is the yardage cost of feeding cattle and is assumed fixed such that:

$$YrdC = 0.40 * DOF \quad (2.10)$$

The 0.40 is the implied cost (per head/day) for cattle feeders located in Kansas and Nebraska.

$FC$  is the per head feed costs defined by:

$$FC = CP * \frac{1}{56} \left( \frac{DMFC}{0.88} * ADG * DOF \right) \quad (2.11)$$

where  $CP$  is the price of a bushel of corn and converted to a per pound basis. Feed conversion is multiplied by the corn based feed ration and assumes 12% moisture.  $VC$  is the per head veterinary costs and  $IC$  is the interest cost calculated as:

$$IC = \left[ \frac{1}{2} (YC + FC + VC) + FeedPurC \right] * DOF * \frac{IR}{365} \quad (2.12)$$

where  $IR$  is an annualized interest rate.

The  $IC$  expression is based on the assumption that there exists a desire to purchase feed throughout the feeding period. The interest charge is imposed to cover the entire amount of cattle feeding costs and one-half the total yardage costs, feed costs, and veterinary costs for the cattle feeder.

To determine how per head cattle feeding profits will respond to changes in fed cattle prices four separate simulations were run to depict varying levels of market risk and its effect on the distribution of profits. The four simulations are based on the implied volatilities drawn from premium rates based on the option contract market. Option contracts are useful because they provide a measure of expected prices and variability based on market outcomes. The four simulations include a high, low, forward contract, and base scenario of expected fed cattle priced while the corn (feed) price is held at an implied volatility level of 32 percent. The high risk scenario was based on an implied fed cattle price volatility of 30 percent, low risk scenario of 20 percent volatility, and a base scenario of 27 percent. In addition, perfect price protection was assumed by considering the forward contract market. Forward contracting eliminates price risk by setting a fed cattle price at the end of the feeding period; therefore an implied volatility of 0 percent was imposed for this particular simulation.

The results from the four profit simulations showed that when fed cattle prices increase the distribution of cattle feeding profits widens. The mean value of profits per head remained relatively unaffected among each simulation while the standard deviation increased considerably. The high and low risk scenarios showed a larger impact on the distribution of cattle feeding profits. The high risk scenario showed a mean profit of \$4.39 per head with a standard deviation of \$297.64. The low risk scenario indicated a mean profit per head of \$3.93 and a standard deviation of \$206.44. In contrast, the forward contract scenario and a mean profit per head of \$3.18 and a standard deviation of \$74.78. The distribution of profits expands as the variances of fed cattle prices increased and the mean per head profits remained relatively constant, suggesting a high probability of large profit losses and gains for the cattle feeder.



## **Conclusions**

Measuring profit variability in fed cattle production provides information that is essential in the development of effective risk management strategies and warrants consideration of cattle yields and market prices. This research provided an assessment of fed cattle profit risks where, given the information available at placement, models were derived and estimated to capture factors that are relevant to the profitability of the cattle feeder. Interaction terms were included to capture the relationship between placement weight and placement season for various measures of yield risk. The incorporation interaction terms allowed information to be gathered that was previously not identified in other studies and was found to have an impact on the management decisions of the cattle feeder.

There are several factors that influence yield risk in cattle feeding. Four regression equations were estimated individually to identify risk associated with cattle yields; dry matter feed conversion, mortality rate, veterinary cost, and average daily weight gain. The gender of the cattle, feedlot location, placement weight, and placement season all play part in the production of fed cattle and need to be considered to minimize yield risk. Lighter weight cattle are generally more efficient at converting feed into weight gain when cattle are placed on feed in the winter and fall months whereas heavier cattle are more efficient at feed conversion when placed on feed in the spring and summer. Knowledge of cattle characteristics and how cattle respond to changes in weather conditions is vital and proper management will translate into cost savings for the cattle feeder.

Ex-ante profit risk was modeled using simulated prices and estimated yields which provided a measure of cattle feeding profits. To identify the effects of profits per head four simulations were run based on various risk scenarios. The simulations showed that although much of the risk can be avoided through price controls, production risk remains. Thus it is

important to create risk management strategies that carefully account for yield risk and matching that with the appropriate price controls.

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## Tables

**Table 2.1 Variable Descriptions and Summary Statistics of fed Cattle closeout data, 1989-2008**

<b>Variable Name</b>	<b>Variable Description</b>	<b>Mean</b>	<b>Std. dev.</b>	<b>Min.</b>	<b>Max.</b>
DMFC	Dry Matter Feed Conversion (lbs. feed/lbs. gain)	6.04	0.54	4.25	10.10
Mortality	Percentage of cattle that die	1.18	1.62	0.00	25.58
VCPH	Vet Cost Per Head (\$/head)	3.43	4.64	0.00	64.58
ADG	Avg. Daily Gain (lbs./head/day)	3.09	0.46	1.55	5.94
InWeight	Avg. weight per head of cattle for the entire pen upon entrance (lbs.)	680.37	110.60	450.00	900.00
OutWeight	Avg. weight per head of cattle for the entire pen upon exit (lbs.)	1173.24	100.84	913.38	1599.07
Steers	Binary variable: 1 if entire pen was steers	0.43	0.49	0.00	1.00
Heifers	Binary variable: 1 if entire pen was heifers (default category)	0.57	0.49	0.00	1.00
KS	Binary variable: 1 if Kansas Feedlot	0.94	0.24	0.00	1.00
NE	Binary variable: 1 if Nebraska Feedlot (default category)	0.06	0.24	0.00	1.00
Summer	Binary variable: 1 if entry between Jun-Aug (default category)	0.26	0.43	0.00	1.00
Winter	Binary variable: 1 if entry between Dec-Feb	0.23	0.42	0.00	1.00
Fall	Binary variable: 1 if entry between Sep-Nov	0.26	0.44	0.00	1.00
Spring	Binary variable: 1 if entry between Mar-May	0.25	0.43	0.00	1.00

**Table 2.2 Conditional Mean and Variance Estimates: Log of Dry Matter Feed Conversion (DMFC) Model**

Variable Name	Conditional Mean				Conditional Variance			
	Base Model		Conditionality Model		Base Model		Conditionality Model	
	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.
Constant	0.7412*	0.0192	0.9686*	0.0348	0.0252*	0.0039	0.0211*	0.0059
Steers	-0.0364*	0.0101	-0.0364*	0.0010	0.1839*	0.0155	0.1779*	0.0155
KS	-0.1016*	0.0019	-0.1013*	0.0019	-0.2814*	0.0317	-0.2822*	0.0315
Log(InWeight)	0.1788*	0.0031	0.1438*	0.0053	0.3694*	0.0488	0.4234*	0.0854
Winter	0.0003	0.0013	-0.4161*	0.0505	0.0535*	0.0199	-1.4902***	0.8076
Fall	0.0009	0.0012	-0.4254*	0.0478	0.0470*	0.0186	0.9143	0.7756
Spring	0.0036*	0.0013	-0.0867***	0.0493	0.0067	0.0198	1.7126**	0.8021
WinLog(InWt)	-	-	0.0639*	0.0078	-	-	0.2366**	0.1239
FalLog(InWt)	-	-	0.0655*	0.0073	-	-	-0.1334	0.1189
SprLog(InWt)	-	-	0.0139*	0.0076	-	-	-0.2621**	0.1230

Note: Single, double, and triple asterisks (\*) denote statistical significance at the 1%, 5%, and 10% levels, respectively

**Table 2.3 Conditional Mean and Variance Estimates: Average Daily Weight Gain (ADG) Model**

Variable Name	Conditional Mean				Conditional Variance			
	Base Model		Conditionality Model		Base Model		Conditionality Model	
	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.
Constant	-5.3002*	0.0867	-6.3084*	0.1533	0.0007*	0.0001	0.0008*	0.0003
Steers	0.2746*	0.0045	0.2749*	0.0045	0.2997*	0.0157	0.2979*	0.0156
KS	-0.1104*	0.0084	-0.1116*	0.0084	-0.3282*	0.0291	-0.3366*	0.0295
Log(InWeight)	1.2856*	0.0133	1.4422*	0.0236	1.9478*	0.0511	1.8799*	0.0929
Winter	0.0208*	0.0057	1.4547*	0.2227	-0.0538*	0.0205	-0.7178*	0.9142
Fall	0.0039	0.0055	1.9967*	0.2105	-0.1296*	0.0202	-2.3915*	0.8245
Spring	-0.0107**	0.0057	0.6821*	0.2170	-0.1172*	0.0213	1.6857*	0.8932
WinLog(InWt)	-	-	-0.2203*	0.0342	-	-	0.1025	0.1402
FalLog(InWt)	-	-	-0.3036*	0.0323	-	-	0.3471*	0.1266
SprLog(InWt)	-	-	-0.1065*	0.0333	-	-	-0.2771*	0.1369

Note: Single, double, and triple asterisks (\*) denote statistical significance at the 1% and 5% levels, respectively

**Table 2.4 Conditional Mean and Variance Estimates: Veterinary Cost per Head (VCPH) Model**

Variable Name	Conditional Mean				Conditional Variance			
	Base Model		Conditionality Model		Base Model		Conditionality Model	
	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.
Constant	18.7953*	0.2829	14.7818*	0.4998	0.0566*	0.0083	0.0725*	0.0182
Steers	0.1725*	0.0146	0.1749*	0.0146	-0.0823*	0.0142	-0.0882*	0.0142
KS	-0.0683**	0.0275	-0.0750*	0.0274	-0.0565***	0.0309	-0.0736*	0.0309
Log(InWeight)	-2.7786*	0.0434	-2.1610*	0.0767	0.9316*	0.0453	0.8569*	0.0769
Winter	-0.2289*	0.0186	7.4556*	0.7261	-0.0376**	0.0187	-1.4858**	0.7512
Fall	-0.0774*	0.0179	2.6922*	0.6862	0.0162	0.0177	1.2199**	0.7567
Spring	-0.1756*	0.0182	6.5538*	0.7076	-0.0501*	0.0188	-1.9663*	0.7610
WinLog(InWt)	-	-	-1.1800*	0.1114	-	-	0.2228**	0.1154
FalLog(InWt)	-	-	-0.4256*	0.1054	-	-	-0.1836	0.1163
SprLog(InWt)	-	-	-1.0343*	0.1087	-	-	0.2955*	0.1170

Note: Single, double, and triple asterisks (\*) denote statistical significance at the 1%, 5%, and 10% levels, respectively

**Table 2.5 Conditional Mean and Variance Estimates: Mortality Rate Model**

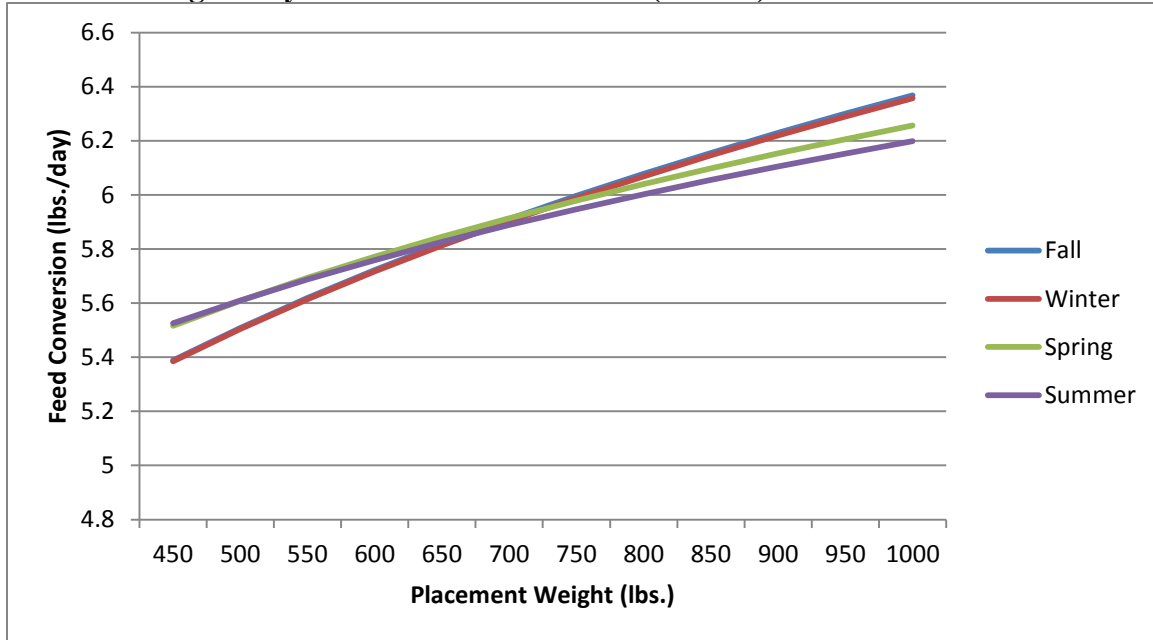
Variable Name	Conditional Mean				Conditional Variance			
	Base Model		Conditionality Model		Base Model		Conditionality Model	
	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.	Parameter Estimate	Std. Dev.
Constant	27.3463*	0.6111	28.2430*	1.1089	332.1096*	79.0051	191.4028**	85.8043
Steers	0.2907*	0.0299	0.2911*	0.0299	-0.0263	0.0238	-0.0235	0.0238
KS	0.2491*	0.0638	0.2589*	0.0640	-0.2791*	0.0493	-0.2905*	0.0493
Log(InWeight)	-4.1583*	0.0936	-4.2980*	0.1701	-1.5053*	0.0735	-1.3333*	0.1388
Winter	-0.0344	0.0391	-1.0415	1.5966	-0.0406	0.0316	-1.6201	1.2968
Fall	0.0618***	0.0372	-1.7340	1.4979	-0.0687**	0.0299	5.4697	1.2413
Spring	-0.0162	0.0369	-0.7103	1.4992	-0.2084*	0.0308	-0.1366	1.2623
WinLog(InWt)	-	-	0.1531	0.2447	-	-	0.2424	0.2001
FalLog(InWt)	-	-	0.2795	0.2292	-	-	-0.8566*	0.1918
SprLog(InWt)	-	-	0.1065	0.2299	-	-	-0.0114	0.1951

Note: Single, double, and triple asterisks (\*) denote statistical significance at the 1%, 5%, and 10% levels, respectively

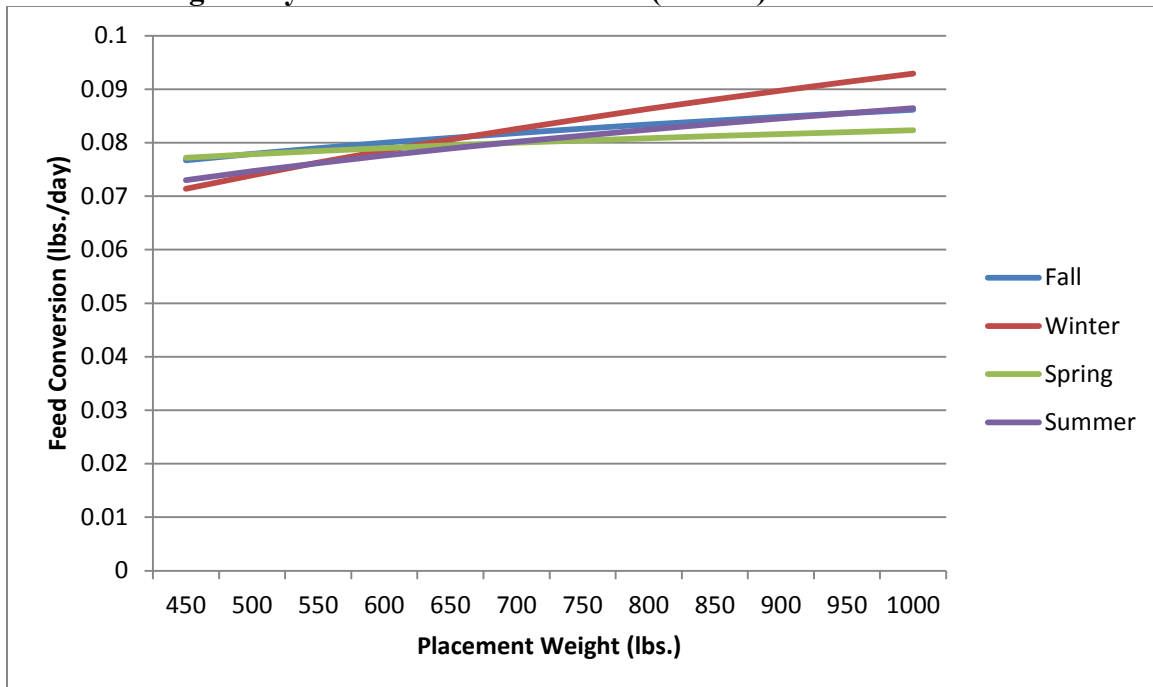


## Figures

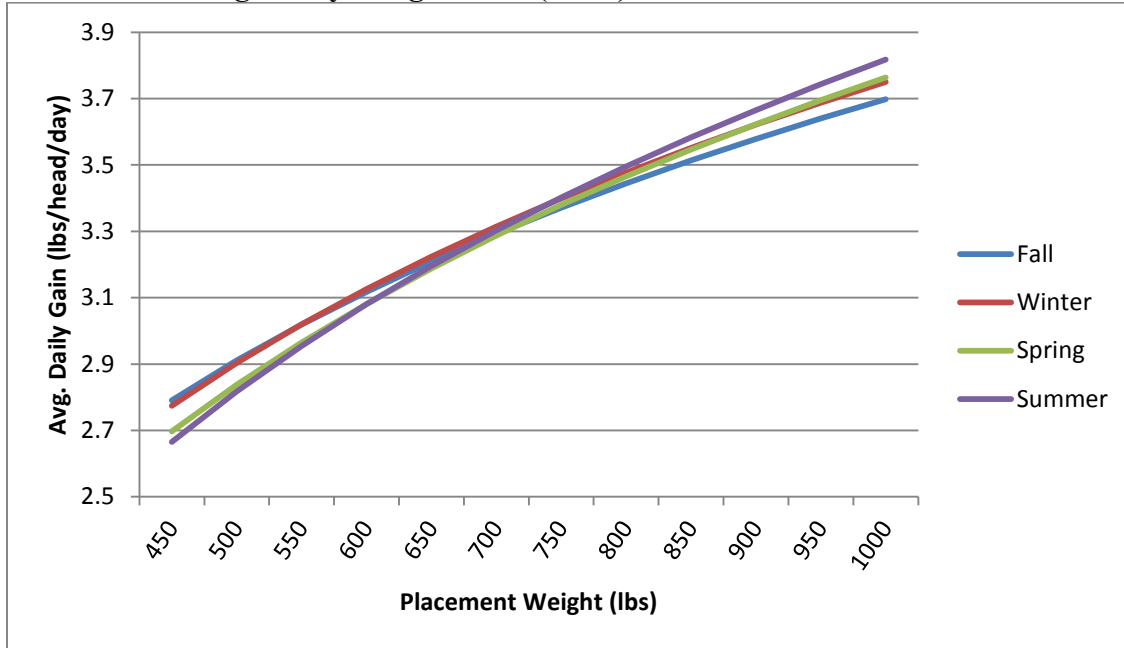
**Figure 2.1 Expected Value of the Interaction between Placement Weight and Placement Season on Log of Dry Matter Feed Conversion (DMFC)**



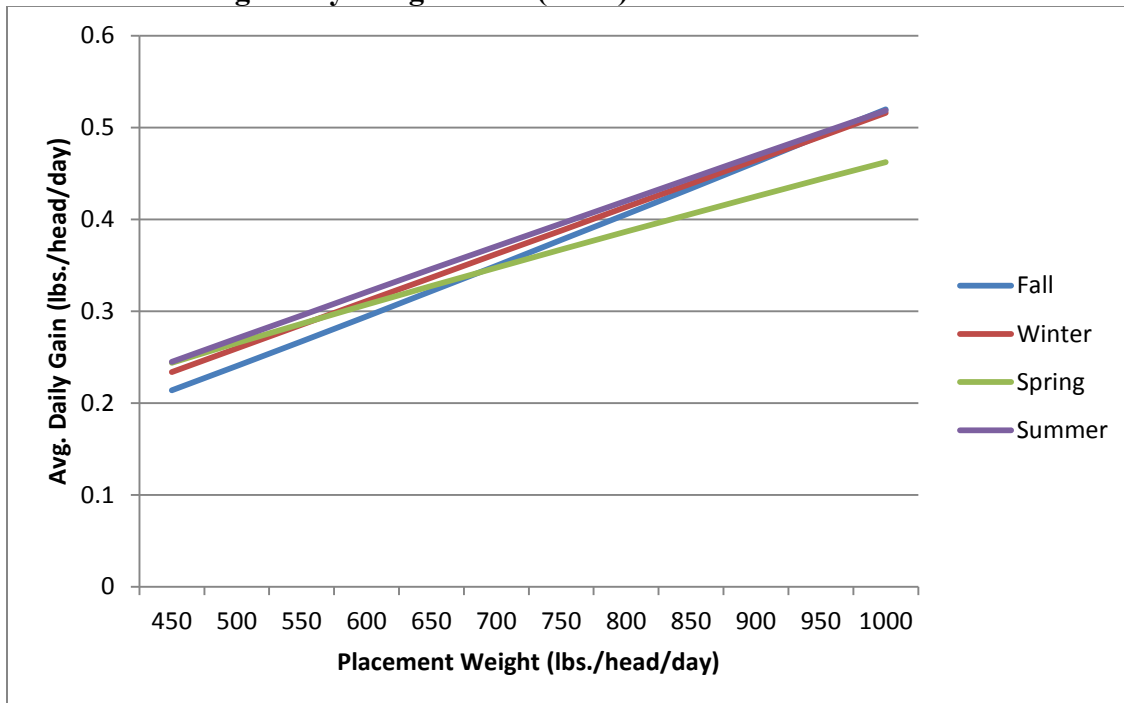
**Figure 2.2 Expected Variance of the Interaction between Placement Weight and Placement Season on Log of Dry Matter Feed Conversion (DMFC)**



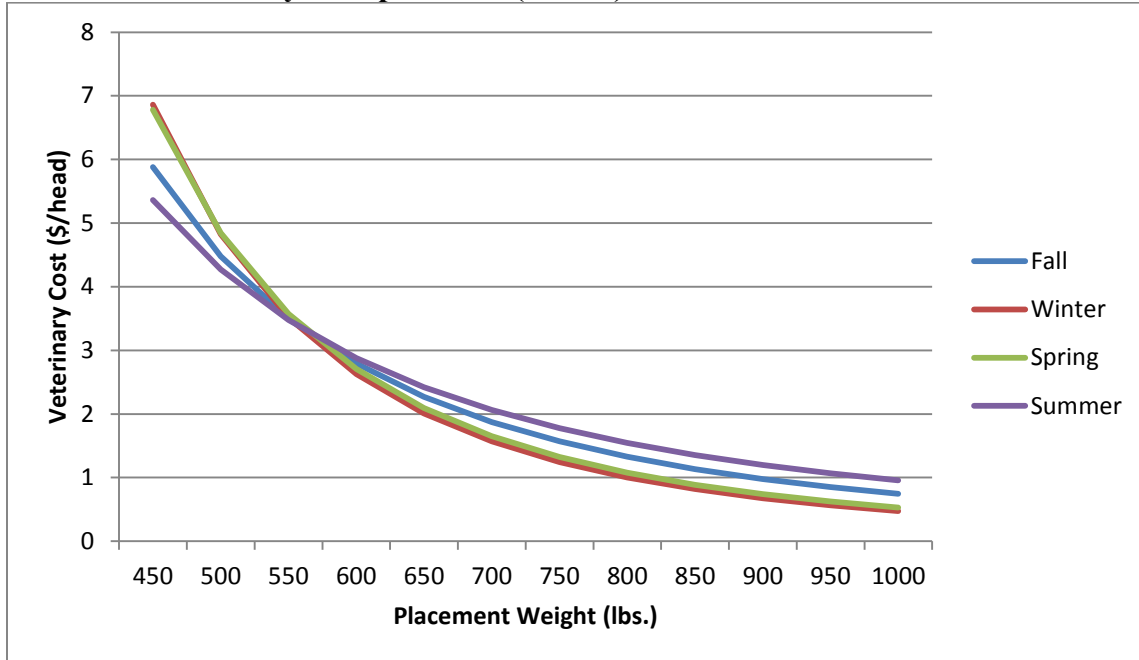
**Figure 2.3 Expected Value of the Interaction between Placement Weight and Placement Season on Average Daily Weight Gain (ADG)**



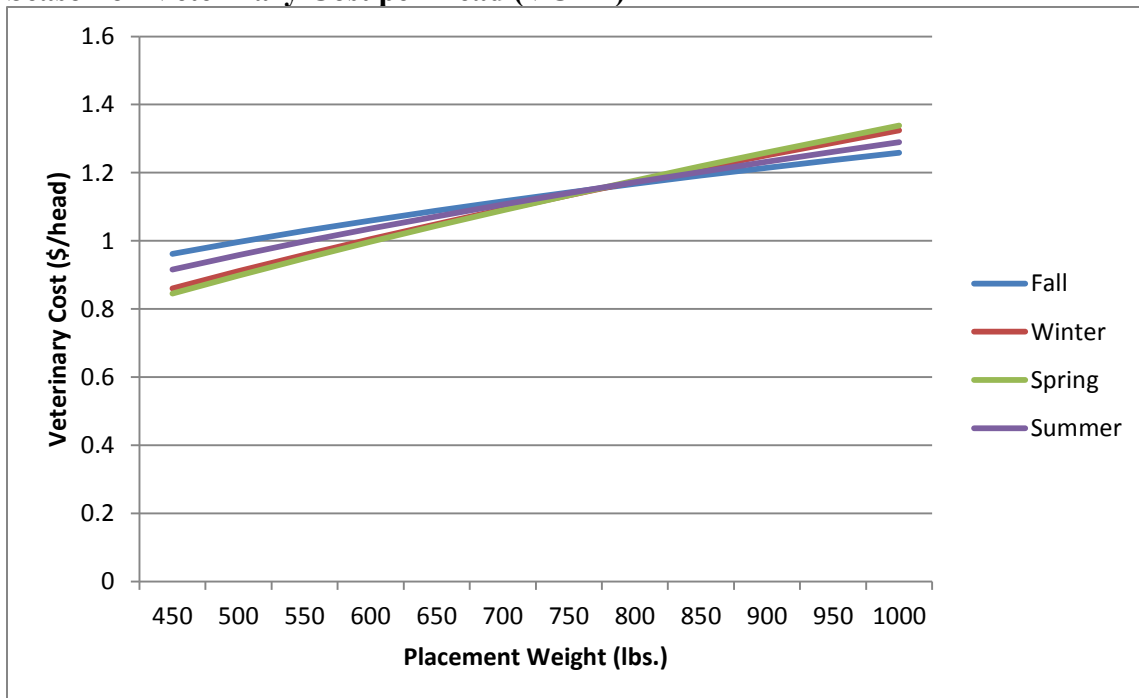
**Figure 2.4 Expected Variance of the Interaction between Placement Weight and Placement Season on Average Daily Weight Gain (ADG)**



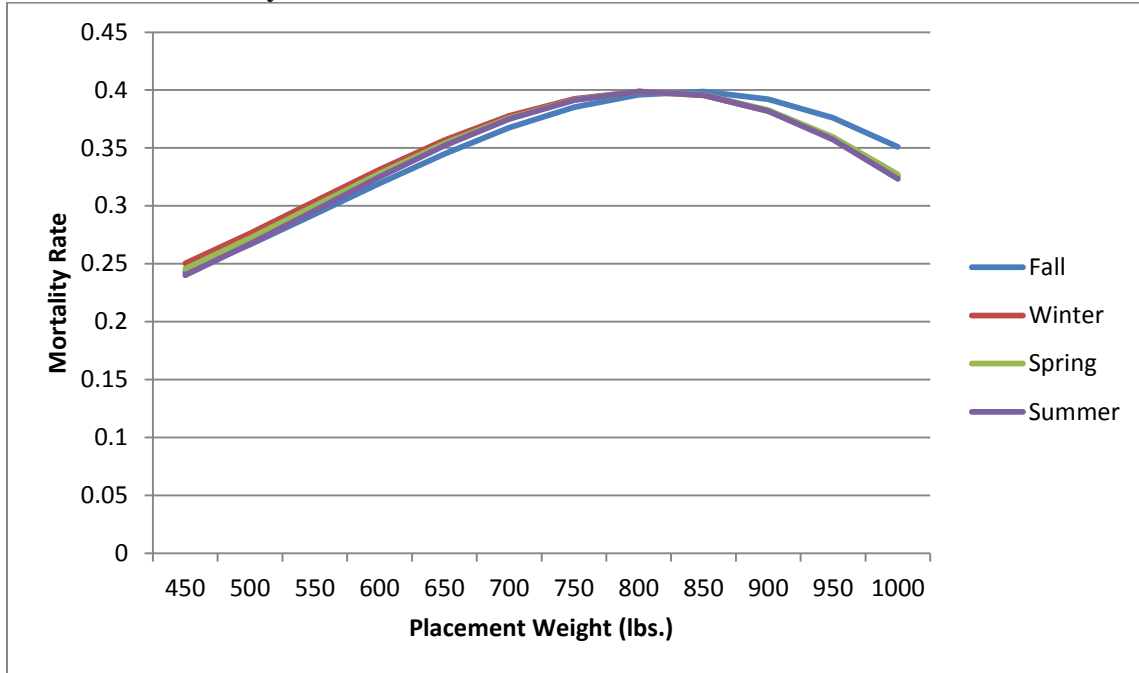
**Figure 2.5 Expected Value of the Interaction between Placement Weight and Placement Season on Veterinary Cost per Head (VCPH)**



**Figure 2.6 Expected Variance of the Interaction between Placement Weight and Placement Season on Veterinary Cost per Head (VCPH)**



**Figure 2.7 Expected Value of the Interaction between Placement Weight and Placement Season on Mortality Rate**



**Figure 2.8 Expected Variance of the Interaction between Placement Weight and Placement Season on Mortality Rate**

