EVALUATION OF THE LIVESTOCK MANDATORY REPORTING ACT ON PRICE TRANSMISSION WITHIN THE BEEF MARKETING CHANNEL

By

JOHNNA LYNN RUSHIN

Bachelor of Science in

Agricultural Economics and Accounting

Oklahoma State University

Stillwater, Oklahoma

2011

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2013

EVALUATION OF THE LIVESTOCK MANDATORY

REPORTING ACT ON PRICE TRANSMISSION

WITHIN THE BEEF MARKETING CHANNEL

Thesis Approved:

Dr. Chanjin Chung

Thesis Adviser

Dr. Derrell Peel

Dr. Brian Adam

.

ACKNOWLEDGEMENTS

I think it is most important to give thanks to where my drive and inspiration came from. To my father, John Rushin, I have never seen anyone work as hard as you. Your continued support while growing up instilled a passion for agriculture and lifelong learning that I will have the rest of my life. To my mother, Lynn Rushin, thank you for the sanity checks and continued encouragement as I pursued higher education. To my sisters, Lynette and Rosina, thank you for serving as such unique mentors.

I cannot express enough thanks to my committee chair, Dr. Chanjin Chung, for his continued support. I thank you for your words of wisdom, countless hours spent helping me, and most especially the funny stories when research was pulling me too far from reality. You truly facilitated the "research" atmosphere and taught me skills that I will use for years to come.

To my committee members, Dr. Brian Adam and Dr. Derrell Peel, I offer my heartfelt thanks for the learning opportunities you have provided me while at Oklahoma State University. You have both effectively watched me grow up, and I cannot thank you enough for your guidance and support.

To the faculty and support staff in the Agricultural Economics department, your continued support, generosity and ability to teach certainly made my transition to and completion of graduate school smoother. Whether it be help with paperwork, serving as a substitute mother for the week or offering life advice, I could not possibly have asked for better. To Anna, Helen, Joyce and the faculty, thank you so much for your time, effort and devotion to the graduate student cohort.

No one would survive graduate school without having people to fall back on and cheer you on. To Brent, Lisa, Seth, Aaron, Annie, Brenna, Amanda and Makayla, I am eternally grateful for all of you. To my classmates, I most definitely would not have excelled without your supportive personalities and honest words. To my friends, I am beyond fortunate to have understanding friends who can always bring me back to my roots.

Name: JOHNNA RUSHIN

Date of Degree: MAY, 2013

Title of Study: EVALUATION OF THE LIVESTOCK MANDATORY REPORTING ACT ON PRICE TRANSMISSION WITHIN THE BEEF MARKETING CHANNEL

Major Field: AGRICULTURAL ECONOMICS

Abstract: This paper evaluates the impacts of the Livestock Mandatory Price Reporting Act (LMRA) on price transmission within the beef marketing channel. Limited empirical studies have examined the effectiveness of the LMRA. The data is split into a pre and post period. Nonlinearity testing finds existence of thresholds in both periods. Thus, we use a threshold error correction model. Two regimes (based off of a threshold value), "IN" and "OUT", were set up. Interestingly, the percentage of observations in the inside regime decreases in the post period as compared to the pre period. Parameter estimates for the retail level in both periods show significant dynamic relationships and appear to show that price adjustments occur more instantaneously inside the threshold. Short-run asymmetry tests indicate the presence of short run asymmetries in the retail-wholesale and retail-farm price relationships in the post-LMRA period. No short run asymmetries on price variables appear to be present in the pre-LMRA period in all price relationships. Adjustment path testing indicates that all price relationships in the pre period experience different adjustment speeds for negative and positive deviations, however, only the wholesale-farm relationship shows a significantly different adjustment speed in the post period. A comparison of parameter estimates between a standard error correction model and a threshold error correction model is used to determine quickness of deviation adjustment speed. For the wholesale-farm price relationship, in both symmetric and asymmetric specifications, deviations appear to adjust faster in the threshold error correction model in the pre period. For the same relationship in the post period, deviations appear to adjust faster in the standard error correction model. Lastly, the process is tested and run again using a truncated data set to mitigate the price volatility that is apparent after 2006. This run shows no nonlinearities and thus uses a standard error correction model.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION AND BACKGROUND

As the concentration ratio in the beef packing industry has risen recently, there has been increasing number of debates on the impact of beef packers' concentration particularly on consumers and producers. Growing unrest over what was thought to be unjust pricing transparency prompted the justification for the United States (US) Congress to implement the Livestock Mandatory Reporting Act (LMRA) of 1999. This act went into effect 2 years later, in April of 2001. Simply put, this act requires large scale packers to report boxed beef transactions to the USDA at a more frequent rate (Ward 2010). Prior to the implementation of the LMRA, a voluntary price reporting system was in place. Thus, the LMRA is known as a mandatory price reporting (MPR) measure. Many producer groups were in favor of the implementation of MPR. The idea was that increased market transparency would provide fairer prices to producers which could be transmitted through the marketing channel to the wholesale and retail levels, and eventually to the consumer (Wachenheim and DeVuyst 2001). There are few quantitative studies over the effectiveness of the LMRA. Many narrative style papers indicate that the LMRA could have had an alternative effect where increased transparency actually benefitted the packer level of the marketing channel more than the producer or retail levels.

Cai, Steigert, and Koontz (2011) use a Markov regime switching model to determine that market power is used in fed cattle markets after the implementation of the LMRA. The authors further go on to state that beef packing margins appear to have increased after the LMRA was implemented. These findings indicate that the act may have created adverse pricing issues after its implementation. Consequently, the growing field of research regarding price transmission levels appears to be relevant to mandatory price reporting. Price transmissions occur when a change in one price causes a change in another price to react differently. For example, does a price change at the farm gate trickle down to a similar price change at the wholesale or retail level? Consider an increase in the price of wheat at the farm level. The relevant question is does the price of flour also increase? Does it decrease? Does the change occur by the same amount?

A common econometric analysis of price transmissions is performed with the use of asymmetric or threshold error correction models. Markov regime switching models, like that of Cai, Steigert and Koontz (2011) are also used to analyze price changes. However, threshold error correction models (TECM) seem to be used more frequently. Ihle and von Cramon-Taubadel (2008) note that, while Markov regime switching models and threshold error correction models allow for nonlinearities and regime changes, they should not be used interchangeably. Specifically, TECM models are characterized by endogenous switching, while Markov switching models are characterized by exogenous switching. Thus, the TECM model may be more appropriate as it more accurately captures and reflects information in the given price series (Ihle and von Cramon-Taubadel 2008).

Returning to the implementation of the LMRA, problems may arise when one level of the marketing channel is able to reap pricing benefits. Consequently, price changes may not transmit at equal rates or at all. These adjustment differences may cause price transmission asymmetries and can be actively studied with the use of a TECM. This paper will investigate the price asymmetries and transmissions in the beef marketing channel in two distinct periods, pre and post implementation of the LMRA. These two dimensions (asymmetries and transmissions) allow for a unique approach in evaluating policy effectiveness for MPR. Studying asymmetries and transmissions will enable an understanding of the shock responsiveness and threshold effects with respect to price adjustments. The use of a TECM will enable the study of both of these dimensions simultaneously.

Generally, the relevant components of price transmission issues are the extent of adjustment (magnitude), the timing of adjustment, and symmetry of adjustments (Vavra and Goodwin 2005). This paper will focus on determining whether nonlinearities (thresholds) and asymmetric adjustments (transmissions) are present in beef prices throughout the marketing channel (i.e. at the farm, wholesale and retail levels). The use of a TECM will enable study of both long and short run price adjustments toward the price equilibrium. Specifically, this paper aims to study the time series properties of beef price data, the correct model representation for gleaning information about beef prices due to the implementation of the LMRA, whether or not the LMRA has impacted asymmetry occurrences, and whether or not the rate of price transmission has changed due to the implantation of the LMRA. These objectives will enable an understanding of the price changes as well as diagnose the working capacity of the beef markets.

Extensive existing research shows that error correction models have been in use for several years. The groundwork was laid by Tong (1983) and Balke and Fomby (1997). In the late 1980s and early 1990s, "pre-cointegration" models were used to determine price transmission asymmetries (APT). Pre-cointegration models were generally just first differenced models used to show some kind of price shift. Kinnucan and Forker (1987) and Boyd and Brorsen (1989) use this type of modeling to estimate APTs in the dairy industry and spatial cattle markets, respectively. More recently, authors have delved into the use of full cointegration models, leading into the use of error correction models.

In perhaps the most relevant piece of research, Goodwin and Holt (1999) analyze asymmetric price adjustments in the US beef sector. The motivation for this research dealt with overall structural changes in the beef industry. Using threshold cointegration and error correction model approaches, the authors are able to conclude that transmissions of shocks are unilateral occurring toward the retail level in the marketing channel. Importantly, Goodwin and Holt (1999) indicate that price responsiveness has increased over time, meaning markets have become more efficient.

The study by Goodwin and Holt was performed using data from 1981 to 1998. Thus, effects of the LMRA would not be included. Those involved in beef production and consumption may benefit from a time advanced study on the possible APTs involved with beef prices. This paper will extend this research to include a more recent time period as well as test price transmissions with respect to a specific piece of legislation, the LMRA. Conceivably, one of the most important factors to consider with the recent time period is the amount of price volatility occurring after 2006. Despite the general trend for prices to shift upward over time, beef prices experienced tremendous volatility after 2006. This can be seen in Figure 1. Given these market changes and the introduction of MPR due to the LMRA, studying price transmissions and asymmetries in the beef marketing channel has become increasingly more important and relevant. The potential change in market transparency caused by the LMRA may have significant effects on price discovery in the beef markets.

Given the potential for the LMRA to have created or to have diminished asymmetries in the beef markets, the underlying data must be properly analyzed in order to determine the appropriate model specifications. For instance, early price transmission studies tended to appear fundamentally linear. However, shocks to the market may not appear or trickle down unless they are of a certain magnitude. Thus, nonlinear models must be and are considered for this study. The idea that shocks may only trigger or appear at a certain level prompt the thought for and use of a threshold error correction model.

This paper will begin with an extensive literature review over both price transmission studies and the LMRA. Next, the justification and use of a threshold error correction model as well as underlying data analysis and testing will be conducted. Specifically, tests for nonlinearities in the data will determine whether the use of a threshold error correction model is appropriate in order to examine possible APTs caused by the implementation of the LMRA. Data and empirical results discussion will be used in order to assess the policy effect of MPR instituted by the LMRA. Discussion will be broken down into a discussion on the time series property of the data, the importance and results of the selected model (TECM), a comparison of error correction models, and the relevancy of the results produced in the selected time period. A discussion of results will wrap up the main findings.

CHAPTER II

REVIEW OF LITERATURE

2.1 Background of Asymmetric Price Transmission

Asymmetric price transmission (APT) has been studied across many commodity groups both in and out of the agriculture industry. Vast amounts of previous research indicate the degree of importance of this subject to economists, producers, and policy makers (respective to each commodity) alike. Price transmission research goes back as far as the late 1950's (Vavra and Goodwin 2005). APT has been a growing research concern over the last few decades with more and more research being emphasized on developing sound econometric models. Research has developed from the previously mentioned dummy variable technique to "pre-cointegration" (first differences) models to full "cointegration models" which tend to involve error correction models.

Much of the published research from the 1980s involves what was called "pre-cointegration" models. Kinnucan and Forker (1987) analyze price transmission asymmetry in the dairy industry and focus heavily on policy contributions to dairy price asymmetry.

Further research has indicated that government intervention can be a source of APT. However, it is typically not the only or main contributing factor (Vavra and Goodwin 2005, Wohlgenant 2006). Kinnucan and Forker (1987) use Gardner's test to show that farm level supply shifts retail prices. This indicates that dairy products grouped as a whole may act different individually. This research was done just after legislation passed downward adjustments in the dairy price support level which lowered retail prices for all tested dairy products (fluid milk, butter, cheese, and ice cream). The contributing conclusion from this study is that retail prices were more sensitive to price increases than price decreases, a finding that has been found in many APT studies. Published research on policy implications regarding price transmission of asymmetry in the beef marketing channel are not known to the author at this time.

Boyd and Brorsen (1989) evaluate price asymmetry in the pork marketing channel and found that underlying cost structures may have been the cause for price transmission asymmetries. This research piece was also a founding point in distinguishing between the impact and the speed of price transmissions, two unique aspects when investigating APTs. The most interesting result relating to the impact of price transmission was that pork wholesalers did not exhibit asymmetric tendencies. Packers responded in the same way to both price increases and decreases. In terms of speed, Boyd and Brorsen (1989) find that the total adjustment of retail prices took at least two weeks longer than the major adjustments to retail prices. Kinnucan and Forker (1987) and Boyd and Brorsen (1989) present very different cases for APT in the agricultural industry, however, the methodologies could not quite pin point the intricacies involved.

2.2 Development of Cointegration and Error Correction Models

The bulk of previous studies have been over farm to retail price transmission due to the indication that causality occurs in this manner. These previous studies [Tweeten and Quance (1969), Boyd and Brorsen (1988), Kinnucan and Forker (1997)] have mostly utilized pre-cointegration methods, however, thus, more recent research indicates that this may not be the best method for measuring APT as the pre-cointegration methods could yield spurious regression results. Goodwin and Holt (1999) utilize threshold cointegration models to test for price linkages in the farm, wholesale, and retail beef markets. This research differs from the previously mentioned studies at its core, because of the model systems used. This study shows a shift from pre-cointegration models into the full use of cointegration and error correction models. More specifically, the authors use a threshold error correction model. Further, the work of Goodwin and Holt (1999) differs as the model systems offer resolve for the time-series properties of the data by considering nonstationary and nonlinear properties of the underlying data. In their work, they use a threshold error correction model is used to evaluate the dynamic time paths of price adjustments to shocks in the U.S. beef marketing channel. Results indicate that price increases were responded to more quickly than price decreases. Goodwin and Holt (1999) further show that farm prices experience the largest adjustment, while markets have become more efficient at transmitting information because responsiveness to price shocks have increased in recent years. This study also finds that causality occurs from farm to retail prices.

Similarly, Goodwin and Harper (2000) analyze the U.S. pork marketing channel. Using a similar cointegration and threshold error correction model enables compatibility for long-run cointegration linkages. The general conclusion that price transmission occurs in one direction (farm to retail) is again confirmed in this study. Like related studies, Goodwin and Harper (2000) suggest that price adjustments at one market level vary with the size of the shock. Results indicate that farm markets adjust to wholesale shocks while retail market shocks are contained within the retail market.

Karantininis, Katrakylidis, and Persson (2011) presented a study on Swedish pork prices using an asymmetric error correction model. The authors report that Swedish pork prices appear to exhibit cointegration between wholesale and retail prices. By adopting asymmetric modeling framework, the authors are able to simultaneously analyze the long run magnitude of price transmission and the short run dynamic adjustment process—something Goodwin and Holt (1999) are unable to do. It is further believed that this may enable better determination of the produced effects of market power (scale versus adjustment costs). However, the authors do not explicitly include market power in this research. One conclusion which concurs with previous literature is that in the short run, only price increases are transmitted. Karantininis, Katrakylidis, and Persson (2011) are able to discuss a slew of results as their model produces results for both the long and short run, but the main cause converges to market power.

2.3 Market Power in Price Transmission Studies

Peltzman (2000) concludes that APT may occur regardless of the degree of concentration in the industry and actually may be a phenomenon which occurs everywhere. He examines 3 markets (producer price, consumer price, and supermarket price samples) with diverse products and finds that the individual decision maker (a supermarket in this case) presents no asymmetry in price response. On the other hand, the author acknowledges above-average asymmetry with cost shocks in fragmented distribution systems. Peltzman believes there is no underlying theory or reason for costs to induce asymmetric lags. In the usual case of market power as a cause for APT, Peltzman (2000) provides a unique, thorough case to show that market power is not (and may not be at all) the case behind APT.

Kimmel (2009) takes an alternative approach from Peltzman in an analytical narrative. Kimmel attempts to solve the puzzle of why competitive industries generally price asymmetrically. Competitive industries are typically not thought of to price asymmetrically, however, in Kimmel's terms, 'real world factors' allow for asymmetrical pricing. Kimmel discusses falling and rising input costs as well as the timing differences each would provide. Both falling and rising input costs are investigated in the following areas: capital and/or asset additions, capital and/or asset reductions, and advertising (addition or lack of). The main take-away regarding the timing issue is that the time required to cut output is substantially smaller than the time required to increase output. The sharp contrast between the results of Peltzman (2000) and Kimmel (2009) indicate the need for more specific research.

McCorriston, Morgan, and Rayner (2001) investigate the concept of underlying cost structures in relation to market power. This research essentially links two suspected causes of APT. In fact, these authors took this concept further and applied it to returns to scale and the combined effects on price transmission. This concept could be immensely useful and relative to the beef industry with varying underlying cost structures and degrees of market power at the different levels of the marketing channel. This returns to scale research does assume that the agricultural product is a homogeneous product.

Further research is needed on different market structures, but McCorriston, Morgan, and Rayner (2001) conclude that market structure has a large effect on who gains and loses. This finding is similar to Kimmel's (2009) proposition. Most notably, the authors show that varying degrees of returns to scale under the influence of market power will be associated with different cost effects and price transmissions. For example, with increasing returns to scale, cost effects (due to scale) could offset market power and alter the level of price transmission present.

2.4 Advanced Price Transmission Studies

Lee and Gomez (2011) investigate the international coffee supply chain between France, Germany and the United States of America (3 largest importing countries). A distinguishing factor of this research is to consider two important issues in price transmission: asymmetry and nonlinearity. Many previous papers claim that they test for both price asymmetry and price linearity (or nonlinearity), but Lee and Gomez note that specific tests must be used in order to test these. They investigate prices (and their characteristics) before and after the elimination of the International Coffee Agreement (ICA) in 1990. Using an extended error correction model, the authors test the two dimensions of asymmetries and nonlinearities. The extended model allows the authors to also investigate short-run responses mostly via nonlinear impulse response functions, a modified version of Potter's (1995) work. Lee and Gomez (2011) conclude that the threshold error correction model is superior to the standard error correction model based on previous literature which indicates threshold error correction models allow for a faster adjustment toward long-run equilibrium.

Integration (or co-integration) tests show that there is a long run relationship among international and retail prices in France, Germany, and the United States. Other results indicate that France does not exhibit asymmetries while Germany and the United States exhibit modest asymmetries during the International Coffee Agreement timeframe. Based on theory, the authors predicted that after the termination of the International Coffee Agreement, speed of adjustment would decrease for France and Germany. Estimated parameters support their predictions. The lengths of price changes and responses differed by each country after the ICA time period, but there is not a similar pattern across the three countries. In terms of the "big picture", final remarks included notation of the existence of threshold effects in terms of long-run adjustments in all three countries for both during and after ICA. Interestingly, the authors conclude that a symmetric model may be a better fit during the ICA period.

Likewise, Vavra and Goodwin (2005) present a comprehensive working paper considering price transmission along the food chain. While this paper is not as specific as that of Gomez and Lee, Vavra and Goodwin (2005) present a large amount of APT history and literature review while empirically testing APT methods. Adjustment problems, "sticky" prices, underlying costs (of adjustments), inventory management strategies, government intervention, and market power are listed as potential causes of APT. One basic conclusion that Vavra and Goodwin conclude, as well as other survey authors (see Meyer and von Cramon-Taubadel 2004), is that no one reason can be secured as the reasoning for APT. An empirical examination is performed on eggs, chicken, and beef. Interestingly, the authors conclude different results for beef than the previous findings by Goodwin and Holt (1999) but note that the difference in time and type of data could be the main contributing factors.

Another comprehensive methodological explanation can be found in the work of Hassouneh, Von Cramon-Taubadel, Serra and Gil (2012). The authors explain recent developments in the price transmission area to provide an explanation of different error correction models and the respective applications of each. The authors present a unique approach to research description by providing references to existing literature, methodology discussions, and lastly, specific model descriptions and background. For a thorough understanding of the differences between linear, nonlinear, asymmetric, continuous, and non-parametric threshold error correction models, this paper would serve as an excellent reference guide.

2.5 The Livestock Mandatory Reporting Act

Varying conclusions are continuously derived from previous research, and actual circumstances across studies rarely seem similar. Taking a closer look at the beef industry, in particular, an increase in the concentration ratio of slaughterhouses has been an increasing concern over the last couple decades. The concern was large enough for the United States Congress to implement procedures thought to enable transparency of prices for producers. Mainly, the Livestock Mandatory Reporting Act (LMRA) of 1999 was introduced and implemented in 2001 (Ward 2010). While it may be easy to use market power as the source of blame for any asymmetries in the beef industry, the multitudes of research in the area indicate there are more causes.

Much theoretical assumptions and conjectures regarding beef prices, transparency effects, and overall changes in the market structure have been published since the implementation of the Livestock Mandatory Reporting Act. MPR does have rules which may exclude some packers. For instance, packers with annual slaughter numbers fewer than 125,000 head are not required to participate in MPR (United States Department of Agriculture 2001). Prices are reported to the USDA Agricultural Marketing Services (AMS), and the act also calls for monthly retail price reporting by the USDA Economic Research Service (ERS). The act does provide some measures to enable protection of the packers. These measures were put into place approximately 5 months after the implementation of the LMRA due to a rocky start on mandatory reporting. This protection guideline is referred to as the "3/70/20" guideline, meaning at least 3 firms must provide prices half the time over the last two months. The protection comes from the rule stating a single firm cannot provide over 70% of the information, and a single firm cannot be the only informant more than 20% of the time over the last 60 days (United States Department of Agriculture 2001). With these factors in mind, producers, packers, policy makers and agricultural economists alike have been left wondering whether or not MPR has been effective.

2.6 Effectiveness of Mandatory Price Reporting

Voluntary price reporting systems had been used as far back as the 1800's, however, growing concentration ratios in the beef industry prompted cause for concern at different production levels. MPR proponents wanted more information and more market transparency. Interestingly, Schroeder, Grunewald, and Ward (2002) indicate that no comprehensive prior research had been completed to actually test the effectiveness (or ineffectiveness, in this case) of the voluntary price reporting system. Further, the research pool for effectiveness of MPR is limited. Only recently, empirical studies have been completed.

In a theoretical study, Azzam (2003) addresses the structure, conduct and performance of the livestock and meat industry using comparative statics on both a downstream and upstream model. Findings show that for a low cost, dominant, reporting packing group, "the act promotes competitive conduct among dominant packers by reducing marginal cost of uncertainty facing all packers and, as a consequence, increasing the derived demand for livestock" (p.394). Azzam's research stresses an important finding regarding MPR: benefits of MPR were not necessarily derived from the new information gathered by producers. In prior research, Wachenheim and DeVuyst (2001) conjecture that when information is 'sufficiently disaggregated', collusion, rather than a more transparent market, may occur. Again, the projection that packers, rather than producers, would benefit is conjectured. Readers are encouraged to refer to this study to fully understand market transparency prior to the implementation of MPR.

Ward (2006) further evaluates the effectiveness of MPR. From the point of cattle feeder satisfaction, results varied geographically. As expected, large commercial feeders were less in favor of MPR than smaller feeders. Another disparity was seen between feeders regarding availability of increased information—57% disagreed to some point. An overwhelming response of feeders regarded that MPR did not aid in price discovery, nearly 75% of respondents. Perhaps the most relative conclusion from Ward's research is that he finds while market transparency has increased, it does not appear to have increased to the point to promote collusive behavior, counterpoint to the projections made by Wachenheim and DeVuyst (2001).

Fausti, Keimig, Diersen, Kim, and Santos (2003) study South Dakota beef markets, specifically, to conclude that pre-MPR price series (voluntary reporting) and public reports were integrated. Thus, even voluntary price reporting was helpful for price discovery and market transparency. This research is closest to our own methodology as it uses cointegration tests and error correction models. However, it is used in a spatial economics context to determine viability of voluntary reporting systems. In another study, Cai, Stiegert and Koontz (2011) use a regime switching model to evaluate fed cattle pricing to determine that market power is used in fed cattle markets after the implementation of MPR. Greater transparency of prevailing livestock prices for producers motivated MPR, and greater transparency was achieved, however, the market transparency trickled through all levels of the beef marketing. Beef packing margins increased after the implementation of MPR (Cai, Stiegert, and Koontz 2011). Limited empirical evidence validating the effectiveness (or ineffectiveness) of MPR leaves ample room for this topic to be reconsidered from the light of cointegration and error correction models.

.

CHAPTER III

METHODOLOGY

A large number of studies exist that have used threshold error correction models to analyze price transmission. Cointegration and error correction models became more frequent in the mid 1990's, and the area of research has only grown since then. Most related, Goodwin and Holt (1999) investigate price relationships in the beef marketing channel. Goodwin and Harper (2000) produced a similar study for the pork marketing channel. Studies cover multiple facets both in and out of the agricultural industry and all across the globe. More recently, Ben-Kaabia and Gil (2005) studied APTs in the Spanish lamb sector, and Lee and Gomez (2011) studied APTs in the international coffee markets. Generally, these studies have confirmed some sort of asymmetry and/or threshold level for price transmissions.

Following the work of Balke and Fomby (1997) to develop threshold cointegration models, a standard price relationship is employed such that:

(1) $RP_t = \alpha_{1,0} + \alpha_{1,1}WP_t + \varepsilon_{1,t}$
(2) $WP_t = \alpha_{2,0} + \alpha_{2,1}FP_t + \varepsilon_{2,t}$
(3) $RP_t = \alpha_{3,0} + \alpha_{3,1}FP_t + \varepsilon_{3,t}$

where RP_t is the retail price level, WP_t is the wholesale price level, FP_t is the farm price level, $\alpha_{1,0}, \alpha_{1,1}, \alpha_{2,0}, \alpha_{2,1}, \alpha_{3,0}$, and $\alpha_{3,1}$ correspond to the respective equation coefficient terms, and $\varepsilon_{1,t}, \varepsilon_{2,t}, \varepsilon_{3,t}$ correspond to the respective error terms. Ordinary least squares results of these regressions enable use of the respective error terms in the following manner (for example, corresponding to equation 1):

(4) $\varepsilon_t = RP_t - \sigma_0 - \sigma_1 WP_t$.

If cointegration is present in the price relationship, the error term symbolizes the deviations from long-run equilibrium. Thus, we can follow the Enders and Granger (1998) approach using a threshold autoregressive representation (TAR) of the error term. First, the representation can be seen as:

(5) $\Delta\varepsilon_t = \rho\Delta\varepsilon_{t-1} + \sum_{i=2}^{k} \gamma_i \Delta\varepsilon_{t-i} + u_t$

where $\Delta\varepsilon_t$ corresponds to the change in the error term (error correction term), ρ is the estimated coefficient, u_t is the error term, and k is the number of lags. Then, delving further into the TAR representation of the error term, the assumption of cointegration and asymmetries indicate the need for a two regime system. This system was primarily developed by Enders and Siklos (2001) and follows:

(6) $\Delta\varepsilon_t = I_1\rho_1^{(OUT)}\varepsilon_{t-1} + (1 - I_t)\rho_1^{(IN)}\varepsilon_{t-1} + \sum_{i=1}^{k}\gamma_i\,\Delta\varepsilon_{t-i} + u_t$

where $I_t$is the Heaviside indicator function assuming I_t=1 if | ε_{t-d}| $\geq \theta$ and I_t=0 if | ε_{t-d}| < θ, $\rho_1^{(OUT)}$ and $\rho_1^{(IN)}$ signify coefficient terms for regime changes, γ_i is the coefficient / parameter term, d is the delay parameter, and k: number of lags. As mentioned, I_t is known as the Heaviside indicator function and serves as the dummy variable which splits the error correction term into different regimes, namely the OUT and IN regime, for this model. The in regime is the period in which error term observations fall within a specified threshold interval (-θ, θ).

First, unit root tests are performed in order to test the stationary properties of the data. The Augmented Dickey Fuller (ADF) test is a widely used unit root test. However, the Phillips Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests offer slightly more robust testing procedures (Maddala and In-Moo 1998). Level data is tested using all three tests. ADF test lag lengths can be determined using the Akaike Information Criterion (AIC) and/or Bayesian Information Criterion (BIC). The null hypothesis for both the ADF and PP tests is nonstationary nature (carrying a unit root). The null hypothesis for the KPSS test is stationary in nature (not carrying a unit root). If level data is concluded to be nonstationary, then first differences of the data must also be tested. If first differences are also nonstationary, then the data must be differenced until the data proves stationary. In the case of stationary first differenced data, the data are said to be of order I(1).

Second, I(1) data must then be tested for cointegration. Johansen's cointegration test uses the price relationship residuals in order to determine the rank of cointegration between the two variables. Both trace and eigenvalue (max) test statistics are used in this study. The null hypothesis for the trace test is the number of cointegrating price vectors is less than or equal to rank r, while the null hypothesis for the eigenvalue (max) test is that cointegration equals rank r (Johansen 1995). If price series appear to be cointegrated, some form of an error correction model needs to be used.

The next step in analyzing the beef price data is to identify whether nonlinearities are present in the data. Tsay (1989) designed an approach which analyzes nonlinearities in autoregressive processes. For Tsay's test, recursive residuals are obtained and regressed on explanatory variables in order to produce an F statistic. This test is useful in not only determining the autoregressive order but also the delay parameter associated with the error correction terms. Tests yielding the largest TAR-F statistic indicate the optimal delay parameter (Lee and Gomez 2011). The null hypothesis is synonymous with linearity in the cointegrating vector. Rejecting the null hypothesis of linearity indicates nonlinearities and possible threshold values.

Chan's (1993) grid search procedure is a frequently used method for obtaining threshold estimates (Lee and Gomez 2011, Goodwin and Holt 1999, Goodwin and Harper 2000). The grid search procedure produces a search for thresholds by analyzing all possible threshold values sorted in order from lowest to highest (in value). The threshold(s) is (are) chosen from this order based on the lowest sum of squared errors (SSE). Lagged residuals from unit root and cointegration tests are used to define the error correction terms for this test. To ensure validity of the thresholds, Hansen (1999) uses a Chow type simulation method in order to test the significance of the threshold estimates. Using bootstrapping procedures and running a number of simulations (100 in this case) will produce asymptotic p-values in order to confirm thresholds and nonlinearities.

After confirmation of cointegration and nonlinearities between price relationships, a threshold error correction model is developed in this study.

This research will split the price relationships into two distinct threshold models, one being a symmetric TECM (STECM) and the other being an asymmetric TECM (ATECM), which uses the positive and negative differences of lagged variables. The symmetric error correction model system of equations, useful for performing long run analysis, can be specified as:

$$\begin{cases} (\mathbf{7})\ \Delta RP_t = \alpha_{1,0} + \alpha_{1,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{1,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{1,j}\, \Delta RP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{1,j}\, \Delta WP_{t-j} + \sum_{j=0}^{k} \delta_{1,j} \Delta EP_{t-j} + \vartheta_{1,t} \\ (\mathbf{8})\ \Delta WP_t = \alpha_{2,0} + \alpha_{2,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{2,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{2,j}\, \Delta WP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{2,j}\, \Delta RP_{t-j} + \sum_{j=0}^{k} \delta_{2,j} \Delta WR_{t-j} + \vartheta_{2,t} \end{cases}$$

$$\begin{cases} (\mathbf{9})\ \Delta WP_t = \alpha_{3,0} + \alpha_{3,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \beta_{3,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{3,j}\, \Delta WP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{3,j}\, \Delta FP_{t-j} + \sum_{j=0}^{k} \delta_{3,j} \Delta WR_{t-j} + \vartheta_{3,t} \\ (\mathbf{10})\ \Delta FP_t = \alpha_{4,0} + \alpha_{4,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{4,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{4,j}\, \Delta FP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{4,j}\, \Delta WP_{t-j} + \sum_{j=0}^{k} \delta_{4,j} \Delta FC_{t-j} + \vartheta_{4,t} \end{cases}$$

$$\begin{cases} (\mathbf{11}) \;\; \Delta RP_t = \alpha_{5,0} + \alpha_{5,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{5,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{5,j}\, \Delta RP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{5,j}\, \Delta FP_{t-j} + \sum_{j=0}^{k} \delta_{5,j} \Delta EP_{t-j} + \vartheta_{5,t} \\ (\mathbf{12}) \;\; \Delta FP_t = \alpha_{6,0} + \alpha_{6,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{6,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{6,j}\, \Delta FP_{t-j} + \\ \qquad \sum_{j=0}^{k} \omega_{6,j}\, \Delta RP_{t-j} + \sum_{j=0}^{k} \delta_{6,j} \Delta CP_{t-j} + \vartheta_{6,t} \end{cases}$$

for each of the three price relationships, where: OUT and IN depict the two regimes, with "OUT" representing those deviations which fall outside of the threshold interval (-θ, θ), and "IN" representing those deviations which fall inside (-θ, θ), similar to that of Lee and Gomez 2011. Variables are as follows: ΔRP_t is a change in retail price; ΔWP_t is a change in wholesale price; ΔFP_t is a change in farm price; EP is an energy price index; WR is a wage rate variable; FC is the feeder cattle auction price; CP is the corn price; $\vartheta_{1,t}$, $\vartheta_{2,t}$, $\vartheta_{3,t}$, $\vartheta_{4,t}$, $\vartheta_{5,t}$, and $\vartheta_{6,t}$correspond to the respective disturbance terms, and k is the number of lags. The above sets of equations are estimated simultaneously using seemingly unrelated regression (SUR). The energy and wage components coupled with the feeder cattle and corn prices are identification variables which aid in determining short run dynamics.

To further investigate the threshold effects and asymmetries, the variables may be split into positive and negative changes (von Cramon-Taubadel and Loy 1996). This splitting creates the ATECM which may be specified by the following system of equations, also estimated using SUR:

$$
\begin{cases}
\textbf{(13)}\ \ \Delta RP_t = \alpha_{1,0} + \alpha_{1,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{1,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{1,j}^{+} \Delta RP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{1,j}^{-} \Delta RP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{1,j}^{+} \Delta WP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{1,j}^{-} \Delta WP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{1,j}^{+} \Delta EP_{t-j}^{+} + \sum_{j=0}^{k} \delta_{1,j}^{-} \Delta EP_{t-j}^{-} + \vartheta_{1,t} \\
\textbf{(14)}\ \ \Delta WP_t = \alpha_{2,0} + \alpha_{2,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{2,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{2,j}^{+} \Delta WP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{2,j}^{-} \Delta WP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{2,j}^{+} \Delta RP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{2,j}^{-} \Delta RP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{2,j}^{+} \Delta WR_{t-j}^{+} + \sum_{j=0}^{k} \delta_{2,j}^{-} \Delta WR_{t-j}^{-} + \vartheta_{2,t}
\end{cases}
$$

$$
\begin{cases}
\textbf{(15)}\ \ \Delta WP_t = \alpha_{3,0} + \alpha_{3,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{3,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{3,j}^{+} \Delta WP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{3,j}^{-} \Delta WP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{3,j}^{+} \Delta FP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{3,j}^{-} \Delta FP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{3,j}^{+} \Delta WR_{t-j}^{+} + \sum_{j=0}^{k} \delta_{3,j}^{-} \Delta WR_{t-j}^{-} + \vartheta_{3,t} \\
\textbf{(16)}\ \ \Delta FP_t = \alpha_{4,0} + \alpha_{4,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{4,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{4,j}^{+} \Delta FP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{4,j}^{-} \Delta FP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{4,j}^{+} \Delta WP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{4,j}^{-} \Delta WP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{4,j}^{+} \Delta FC_{t-j}^{+} + \sum_{j=0}^{k} \delta_{4,j}^{-} \Delta FC_{t-j}^{-} + \vartheta_{4,t}
\end{cases}
$$

$$
\begin{cases}
\textbf{(17)}\ \Delta RP_t = \alpha_{5,0} + \alpha_{5,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{5,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{5,j}^{+} \Delta RP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{5,j}^{-} \Delta RP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{5,j}^{+} \Delta FP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{5,j}^{-} \Delta FP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{5,j}^{+} \Delta EP_{t-j}^{+} + \sum_{j=0}^{k} \delta_{5,j}^{-} \Delta EP_{t-j}^{-} + \vartheta_{5,t} \\
\textbf{(18)}\ \Delta FP_t = \alpha_{6,0} + \alpha_{6,1}^{(OUT)} I_t \hat{\varepsilon}_{t-1}^{(OUT)} + \alpha_{6,1}^{(IN)} (1 - I_t) \hat{\varepsilon}_{t-1}^{(IN)} + \sum_{j=1}^{k} \beta_{6,j}^{+} \Delta FP_{t-j}^{+} + \\
\sum_{j=1}^{k} \beta_{6,j}^{-} \Delta FP_{t-j}^{-} + \sum_{j=0}^{k} \omega_{6,j}^{+} \Delta RP_{t-j}^{+} + \sum_{j=0}^{k} \omega_{6,j}^{-} \Delta RP_{t-j}^{-} + \\
\sum_{j=0}^{k} \delta_{6,j}^{+} \Delta CP_{t-j}^{+} + \sum_{j=0}^{k} \delta_{6,j}^{-} \Delta CP_{t-j}^{-} + \vartheta_{6,t}
\end{cases}
$$

where the variables are the same as those in the STECM.

Using SUR enables a better interpretation of the standard errors obtained with the estimates as the errors will be linked via the error terms for the cointegrated relationships. Lags on the variables are chosen using the AIC statistics in order to limit the occurrence of autocorrelation between residuals. Coefficients of lagged variables can be used both to analyze transmissions and to test asymmetry hypotheses For instance, testing whether or not the positive change in a split variable is equal to a negative change in a split variable will provide a test of short run asymmetry. For example, in equation 18, H_0: $\Delta RP_{t-j}^{+} = \Delta RP_{t-j}^{-}$ will test short run asymmetries exist in the retail-farm price relationship. Equilibrium adjustment path tests can be performed by utilizing an F-test such that the in and out coefficients are equal to 0 for all lags in the same time period, i.e. H_0: $\alpha_{i1}^{(OUT)}=\alpha_{i1}^{(IN)}=0$. This test will analyze whether a return to equilibrium post shock is possible.

CHAPTER IV

DATA

Beef prices were collected via the Livestock Marketing Information Center (LMIC). Fed cattle prices (farm level prices, FP) and boxed beef prices (wholesale level prices, WP) are from the United Stated Department of Agriculture (USDA). Fed cattle prices (FP) are reported as Kansas live, choice 1000-1100 pounds. Boxed beef prices (WP) are reported as a composite from different cuts into a boxed beef cutout value. Both fed cattle and boxed beef prices are reported in dollars per hundredweight. Retail prices (RP) are from the USDA Economic Research Service (USDA-ERS) and the Bureau of Labor Statistics (BLS). Retail prices are reported in terms of dollars per pound.

Four identification variables include fuel, wage, feed and cattle inputs. Respectively, the variables are the number (no.) 2 diesel fuel producer price index (PPI), average weekly earnings of production and nonsupervisory employees in the animal slaughtering and processing industry, a national corn price average, and average Oklahoma City feeder cattle auction prices. Identification variables are used primarily to analyze short-run effects. The no. 2 diesel fuel PPI was obtained from the Bureau of Labor Statistics energy price index for fuels and power with a 1982 base year.

The wages component was also obtained from the Bureau of Labor Statistics and is a national value developed from the Current Employment Statistics (CES) survey in 1982-1984 U.S. dollars. USDA National Agricultural Statistics Service (USDA-NASS) national average corn prices are reported in dollars per bushel. Feeder cattle auction prices were retrieved from the LMIC and account for the 7-800 pound steer range.

All data sets are monthly variables represented from January 1987 to December 2012. Line graph representations of the individual data series may be seen in Figures 1-5. Descriptive statistics of the data are provided in Table 1. Weekly series for farm level and wholesale level price data are available. However, data extrapolation would have to be performed in order to use a weekly retail price. Monthly prices were the reported frequency most available to the author. Other studies have used a weighted average approach to develop a weekly series. However, the issue of aggregation bias may affect results. Thus, this paper will use monthly variables.

.

CHAPTER V

RESULTS

Section 1. Unit Root and Cointegration Tests

The Augmented Dickey Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski, Phillip, Schmidt and Shin (KPSS) procedures are used to test for unit root of variables. First, data for the pre-LMRA period are tested. Results are reported in Table 2. For level data prior to the LMRA implementation, ADF and PP tests fail to reject for the null hypothesis of nonstationarity, indicating the data may carry a unit root. KPSS tests, overall, indicate a rejection of the null hypothesis of stationarity. Between the ADF, PP, and KPSS tests, level data for the pre-LMRA implementation period is said to be nonstationary and carry a unit root. Thus, first differences of the data are taken and tested. ADF and PP tests for first differenced data in the pre-LMRA period indicate a rejection of the null hypothesis of nonstationarity. Thus, first differenced price data are said not to carry a unit root and maintain stationary properties. This is further confirmed by the KPSS test which, overall, fails to reject of the null hypothesis stating stationarity. Therefore, level data is nonstationary and first differenced data are stationary for the pre-LMRA period.

Similarly, data for the post-LMRA period are tested. Results are reported in Table 3. Level data for the post-LMRA implementation period indicates nonstationarity overall. ADF and PP tests all fail to reject the null of nonstationarity, indicating that the level data carry a unit root. KPSS tests confirm this by rejecting the null of stationarity. Due to the nonstationary nature of the level data, first differences are tested for stationarity in the post-LMRA period. ADF tests and PP tests reject the null of nonstationarity for first differenced data. The stationary nature of the first differenced data is again confirmed by the KPSS test which fails to reject the null of stationarity in all cases. Thus, for the post-LMRA period, level data is said to be nonstationary and carry a unit root while first differenced data is said to be stationary and does not carry a unit root.

Varying lag lengths for the ADF tests are determined using minimum information criteria statistics, specifically the Akaike Information Criteria. Statistical software verified that an appropriate KPSS lag length is 4 for both time periods. As the ADF test is known for its limitations, mostly regarding serial correlation, the PP and KPSS tests were also used. PP tests are slightly more robust (than ADF tests) and do correct for some of the ADF test's downfalls (Maddala and Kim 1998). KPSS testing ensures another check for proper testing. All tests are performed at the 5% significance level. ADF and PP tests are performed using the following three specifications: no intercept, intercept, and trend models. KPSS tests are performed for two specifications, intercept and trend models. Stationary first differenced price series are said to be of order I(1). Nonstationary level data and stationary first differenced data satisfy the conditions for moving into Johansen cointegration analysis. Unit root and cointegration tests are performed using the statistical software package, SAS 9.3.

Three pairs of prices are tested for cointegration both before and after the implementation of the LMRA. Results are presented in Table 4. The tested pairs include 1) farm price and wholesale price, 2) wholesale price and retail price, and 3) farm price and retail price. Linear cointegration tests are performed using Johansen's cointegration testing method (Johansen 1995). Table 4 shows trace and λ_{max} statistics for the three price relationships and two time periods. Lag lengths vary and are indicated in parentheses. Lag lengths were, again, selected based on minimum information criterion tests, specifically the Akaike Information Criteria. Statistics are analyzed at the 5% significance level. Reported numbers are from the non-restricted model, meaning the drifts are constant (versus a linear process drift). All series indicate a cointegrated relationship between the price pairs. All series also indicate the presence of cointegration of rank 1. With at least one cointegrated price vector in each time period, conditions for moving into error correction modeling are satisfied.

Section 2. Nonlinearity Tests

A necessary test to perform in order to use a threshold error correction model is a test of nonlinearities in data and relationships. Ordinary Least Squares (OLS) estimates of the cointegrating price relationships provided error correction terms in order to perform Tsay's test (1989). Similar procedures were performed by Goodwin and Holt (1999) as well as Goodwin and Harper (2000). The error correction terms are then used to develop the threshold autoregressive (TAR) equation. Tsay's (1989) and Hansen's (1999) tests are used to verify nonlinearities and need for thresholds in specifying error correction models. Both nonlinearity tests are conducted using the statistical software, *R*. The "tsa" and "tsDyn" libraries were used for Tsay's (1989) and Hansen's (1999) tests, respectively. Results for tests of nonlinearities can be seen in Table 5. Using the obtained residuals, Tsay's test is used for selection of delay parameters. Minimum information criterion was used in order to determine the optimal lags associated with the autoregressive order. Delay parameters were selected based on the highest TAR-F statistic (Goodwin and Holt 1999). Delay parameter estimates increase between the pre and post period, indicating that error correction process is larger in the post period. Thus, regime switching actually becomes less immediate after the implementation of the LMRA. Tsay's test results indicate that nonlinearities are present. The null hypothesis of linearity in the cointegrating vector is rejected in all price relationships both pre and post LMRA implementation. The tests were performed at the 5% significance level.

After confirming nonlinearities, the next step is to obtain threshold values. Threshold values may be obtained via Chan's grid search procedure (1993). This procedure minimizes the sum of squared errors on organized error terms in order to determine optimal threshold values. Obtained threshold values can be seen in Table 5. The grid search procedure is also conducted using the statistical software, *R*. Specifically, the "tsDyn" library in *R* is used. Interestingly, threshold magnitudes increase between the pre and post periods, but percentage inside the regime decreases between the pre and post periods. Also seen in Table 5, the Hansen (1999) test, which used 100 bootstrapping replications, confirms nonlinearities with the threshold parameters by rejecting the null hypothesis of no threshold effects across the board. Minimum information criteria were used to determine optimal lag structures for the grid search procedure and Hansen's nonlinearity tests. Results for Tsay's test, Hansen's test, Chan's grid search procedure, threshold estimates and their corresponding optimal lags and delay parameters can be seen in Table 5.

Section 3. Parameter Estimates and Price Transmission

Parameter estimates for the symmetric and asymmetric threshold error correction models are presented in Tables 6-11. Results are reported for estimates obtained using Seemingly Unrelated Regression (SUR) via the Proc Syslin procedure in SAS 9.3. Parameter estimates for the OLS and SUR equations were similar, but the differences are observed in the standard errors as the standard errors for SUR derived equations are related through error terms The coefficients for error correction terms, ε_{t-1}^{OUT} and ε_{t-1}^{IN}, indicate a long run speed of adjustment toward each respective regime. The out regime may be interpreted as those deviations which fall outside the threshold interval (-θ, θ) (Lee and Gomez 2011).

For the retail-wholesale relationship in the pre-LMRA period (seen in Tables 6 and 9), the outside threshold error terms are significant indicating responsiveness and interrelationship. A similar retail-wholesale relationship can be seen for the inside threshold regime in the post-LMRA relationship. These relations indicate significant dynamic relationships among these price series. These results are observed in both the symmetric and asymmetric threshold error correction models. Interestingly, the coefficients for these significant price relationships are not similar in nature (sign). For the "OUT" regime in the retail-wholesale relationship, parameter estimates decrease between pre and post period from both symmetric and asymmetric models. This relationship indicates that price adjustments are occurring more instantaneously in the post period than the pre period. The same situation occurs for the "IN" regime.

However, not all parameters for the “IN” regime are statistically significant. The overall decreasing parameters between periods in the retail-wholesale relationship agree with the overall goal of the LMRA. Adjustment in the post period appears to decrease at an increasing rate (as compared to the pre period) which may be synonymous with an increase in price transparency created by the LMRA.

For the wholesale-farm relationship (seen in Tables 7 and 10), neither regime (in either model) possesses overall statistical significance, however, parameter estimates for the “OUT” regime are all positive (for both periods and both the symmetric and asymmetric models). This indicates an increase in the adjustment for the out regime. This result is counterpoint to what was observed in the “OUT” regime for the retail-wholesale equation. Further, this increase in adjustment speed between the wholesale and farm prices is counter to the overall purpose of the LMRA. Along the same lines, the “IN” regime for the retail-farm price relationship (seen in Tables 8 and 11) indicates negative coefficients in both models and both time periods. Thus, the price relationship is said to have a decreasing adjustment in the “IN” regime, however, these results must be interpreted carefully as not all parameters are statistically significant. Again, this decreasing relationship would be synonymous with the purpose of the LMRA to increase market transparency.

Section 4. Asymmetries

4.1 Short Run Asymmetry Tests

Given the asymmetric nature indicated by the nonlinearities present, short run asymmetry tests are performed on each set of split (positive and negative) first differenced independent variables given in equations 13-17. Results for short run asymmetry tests can be seen in Tables 12-14, and all tests are performed at the 5 and 10% significance levels. The null hypothesis for this test is symmetry. For the retail-wholesale relationship, given the wholesale identification variable in the change in retail price equation, a symmetric nature appears to be more appropriate for the pre period while an asymmetric nature appears to be more appropriate for the post period. This can be confirmed by the F statistics reported in Table 12. The relationship using the change in wholesale price as the dependent variable indicates no significance in any of the tested independent variables for short run asymmetries.

For the wholesale-farm price relationship (seen in Table 13), short run asymmetries appear to be present in the wholesale price independent variable for the change in farm price equation for the post-LMRA period. Again, the pre-LMRA period indicates no short run asymmetries. The short run asymmetry results for the retail-farm price relationship can be seen in Table 14. Neither of the independent variables correlating to the opposite dependent variable (i.e. the lagged change in farm price independent variable in the change in retail price equation), reject the null, indicating overall symmetry. However, for the change in retail price equation, short run asymmetries do appear for the lagged change in retail price. Uniquely, the lagged change in the energy component (identification variable) shows short run asymmetries in both periods for the change in retail price equation.

4.2 Equilibrium Adjustment Paths

The "IN" and "OUT" regime components indicated in equations 13-17 are tested in order to investigate momentum equilibrium adjustment path asymmetries. This is again done based on price pair relationships. Results for these tests may also be seen in

Tables 12-14. The null hypothesis for testing equilibrium path asymmetries is tests the coefficients for the error correction terms, $\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$. Essentially, this test examines the potential to return to equilibrium after a shock (Ning and Sun 2012). Tests are performed at the 5 and 10% significance level. Corresponding coefficients for each of these parameters, respective to the price pair relationships, can be seen in Tables 9-11.

Upon investigating the transmission between retail price to wholesale price (Table 9), the "OUT" regime parameter appears to be significant in the pre-LMRA period. The same situation occurs in the wholesale to retail relation (wholesale equation). However, this parameter is negative (again for the pre-LMRA period). The equilibrium adjustment path hypothesis (seen in Table 12) for this relationship is rejected for the pre-LMRA period in the change in retail price equation and is significant at the 5% level. This indicates that, statistically, a difference in speed responsive to positive and negative deviations occurs.

Parameter estimates for the wholesale-farm price relationship can be seen in Table 10 while the equilibrium adjustment path test can be seen in Table 13. The "OUT" regime appears statistically significant at the 10% level for both equations in the pre-LMRA period. Again, this indicates that speed responsiveness to positive and negative differences is statistically different and significant. Similarly, parameter estimates and equilibrium path adjustment tests can be seen in Tables 11 and 14, respectively, for the retail-farm price relationships. For the retail to farm transmission (noted by the retail equation), the "OUT" regime shows statistically significant parameters for both periods. The equilibrium adjustment path test is rejected for the pre-LMRA period at the 5% level (seen in Table 14). Again, this indicates that the response speed of adjustment to positive and negative differences is statistically different and significant. Post-LMRA adjustment path tests for the retail-farm price relationships are not rejected.

Section 5. Comparison with Standard Error Correction Models

5.1 Symmetric Specification

Tables 15-17 present parameter estimates for the standard error correction model with a symmetric representation. These parameter estimates can be compared to those presented in Tables 6-8 for the threshold error correction model symmetric representation. For the symmetric retail-wholesale relationship in the pre-LMRA period, it appears that deviations from equilibrium experience similar overall adjustment in the threshold and standard error correction model. For the symmetric wholesale-farm relationship in the pre-LMRA period, results are more convoluted but appear to generally indicate that deviations adjust more quickly for the symmetric threshold model. On the other hand, deviations in the retail-farm relationship in the pre-LMRA period appear to adjust more quickly in the standard error correction model rather than the threshold error correction model. Results for the retail-wholesale relationship in the post-LMRA period are not as conclusive with varying parameter estimates in both models. No set appears to adjust faster in all variables, overall. For the wholesale-farm relationship in the post-LMRA period, it appears deviations experience faster adjustment processes in the standard error correction model. Lastly, for the retail-farm relationship in the post-LMRA period, neither model indicates an overall quicker adjustment process when compared to the other.

5.2 Asymmetric Specification

Tables 18-20 present parameter estimates for the standard error correction model with an asymmetric representation. These parameter estimates can be compared to those presented in Tables 9-12 for the threshold error correction model with asymmetric representation. For the retail-wholesale relationship in the pre-LMRA period, it appears the deviations may adjust more quickly in the standard error correction model. For both the wholesale-farm and retail-farm relationships in the pre-LMRA period, deviations appear to adjust to equilibrium at a faster rate in the asymmetric threshold error correction model rather than the standard error correction model. For the retail-wholesale relationship in the post-LMRA period, neither model indicates an overall quicker adjustment process when compared to the other. For both the wholesale-farm and retail-farm relationships in the post-LMRA period, deviations appear to adjust to equilibrium at a faster rate in the standard error correction model (with an asymmetric representation) rather than the asymmetric threshold error correction model.

Section 6. Use of a Truncated Data Set

Prior conclusions of asymmetries in the post-LMRA period may prompt scrutiny due to the years included in the full data set. Looking at Figures 1-5, in all price series, prices after the year 2006 appear to be quite volatile. This appearance of price volatility in the market coupled with an upward trend over time has prompted the use of a truncated data set. Thus, the same procedures are run for a limited data set ranging from January 1996 to April 2001 for the pre-LMRA period and May 2001 to December 2006 for the post-LMRA period. Table 21 shows descriptive statistics of the truncated data set. Similar to the full data set, level price series in both the pre and post LMRA period appear to be nonstationary. Thus, first differences of the price series (in both periods) are taken and tested. First differenced data appear to be stationary in nature. Again, the

ADF, PP and KPSS tests are used to test for stationarity. Results can be seen in Tables 22 and 23 for the pre and post periods, respectively.

After confirming stationary first differenced data in both time periods, Johansen's cointegration tests was also performed on the truncated data set. Results can be seen in Table 24. Again, cointegration is present in all price relationships in both time periods. Thus, the next step is to test for nonlinearities. However, the null hypothesis for Tsay's test of a linear process cannot be rejected in all price relationships in both the pre and post LMRA periods. A standard error correction model appears to be more appropriate due to linearities in the autoregressive process, rather than the previously seen nonlinearities. Standard error correction model results can be seen in Tables 25-27.

For the retail-wholesale relationship in both periods, significance in the lagged wholesale price can be seen. For the wholesale-farm relationship with the wholesale price as the dependent variable, the lagged change in farm price is statistically significant. The retail-farm relationship in the pre-LMRA period shows that the lagged farm price is statistically significant while in the post-LMRA period, both the lagged retail and farm prices are statistically significant.

CHAPTER VI

CONCLUSION

This study examined the nature of price transmissions and asymmetries among the farm, wholesale, and retail levels of the beef marketing channel. Using threshold error correction models, transmissions and asymmetries were analyzed before and after the implementation of the LMRA. The time-series properties of the data were considered using numerous unit root testing procedures as well as by performing cointegration tests for pairwise price relationships. Tests of nonlinearity confirmed possible asymmetries and need for threshold error correction modeling. Analysis of parameter estimates and hypothesis testing allowed for a thorough investigation of price transmissions and asymmetries. Unit root testing on first differenced data indicated stationary data, and cointegration tests in both time periods yielded results showing cointegration in all pairwise vectors. This coupled with rejected linearity tests prompted the use of symmetric and asymmetric threshold error correction models.

Parameter testing investigated the dynamic relationships between price variables and the threshold regimes. A decrease in parameter estimates between the two periods for the retail-wholesale price relationship indicated that price adjustments occur more instantaneously after the implementation of the LMRA. Short run asymmetry tests produced F statistics indicating whether or not a symmetric or asymmetric nature was more appropriate. For the retail-wholesale and wholesale-farm relationships in the pre-LMRA period, the null hypothesis of symmetry could not be rejected, indicating that for those relationships, a symmetric nature is more appropriate. So far, these results are consistent with increased transparency provided by the LMRA. Results are varied for the post-LMRA period. For the wholesale-farm price relationship, using the change in farm price as the dependent variable, post-LMRA period data show asymmetric short run nature. The same can be said for the retail-wholesale relationship. Transmissions and asymmetries appear to be more statistically significant in the retail-wholesale and wholesale-farm relationships than the retail-farm relationship. Thus, the varying relationships are not all consistent with the goal of the LMRA.

The variability in asymmetry results coupled with the transmission results certainly show that the LMRA may have policy implications opposite of what was expected. However, these results must be interpreted with caution as price volatility in the post-LMRA period was paramount. Thus, a truncated data set was analyzed and showed not to possess nonlinearities in the data. Standard error correction models show some significance in short run independent variables.

A comparison of standard error correction models for the full time length showed widely varying results. For the pre-LMRA period, a symmetric model specification showed that for the retail-wholesale and wholesale-farm price relationships, a threshold error correction model indicated a faster adjustment process while the retail-farm relationship showed that the standard error correction model shows a faster adjustment process. On the other hand, the asymmetric model specification shows that both the wholesale-farm and retail-farm price relationships had faster adjustment in the threshold error correction model, while the retail-wholesale relationship had a faster adjustment in the standard error correction model. For the post-LMRA period, the symmetric results are mixed, but the asymmetric results showed that for the wholesale-farm and retail-farm relationships, a standard error correction model showed faster adjustment processes.

REFERENCES

Azzam, A. 2003. "Market Transparency and Market Structure: The Livestock Mandatory Reporting Act of 1999." *American Journal of Agricultural Economics* 85(2): 387-395..

Balcombe, K., A. Bailey, and J. Brooks. 2007. "Threshold Effects in Price Transmission: The Case of Brazilian Wheat, Maize, and Soya Prices." *American Journal of Agricultural Economics* 89(2): 308-323.

Balke, N.S., and T.B. Fomby. 1997. "Threshold Cointegration." *International Economic Review* 38(3): 627-645.

Ben-Kaabia, M. and J.M. Gil. 2005. "Asymmetric Price Transmission in the Spanish Lamb Sector." Paper presented at the XIth Congress of the European Association of Agricultural Economists, Copenhagen Denmark, August 24-27.

Boyd, M., and B.W. Brorsen. 1988. "Price Asymmetry in the U.S. Pork Marketing Channel." *North Central Journal of Agricultural Economics* 10(1): 103-109.

Bureau of Labor Statistics. 2013. *Consumer Expenditure Survey Database*. Washington D.C.: Bureau of Labor Statistics. Available at: http://www.bls.gov/ (last accessed March 1, 2013).

Bureau of Labor Statistics. 2013. *Producer Price Indexes Database*. Washington D.C.: Bureau of Labor Statistics. Available at: http://www.bls.gov/ (last accessed March 1, 2013).

Cai, X., K.W. Stiegert, and S.R. Koontz. 2011. "Oligopsony Fed Cattle Pricing: Did Mandatory Price Reporting Increase Meatpacker Market Power?" *Applied Economics Perspectives and Policy* 33(4): 606-622.

Chan, K.S. 1993. "Consistency and Limiting Distribution of the Least Squares Estimator of a Threshold Autoregressive Model." *The Annals of Statistics* 21(1): 520-533.

Conforti, P. 2004. "Price Transmission in Selected Agricultural Markets." Working paper, FAO Commodity and Trade Policy Research.

Dickey, D.A., and W.A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." Journal of the American Statistical Association 74(366): 427-431.

Fausti, S.W., R. Keimig, M. Diersen, H. Kim, and J. Santos. 2003. "Mandatory Versus Voluntary Price Reporting: An Empirical Investigation of the Market Transparency Controversy." Paper presented at the Southern Agricultural Economics Association.

Enders, W. 2004. *Applied Econometric Time Series*. New York: John Wiley & Sons, Inc.

Enders, W., and P.L. Siklos. 2001. "Cointegration and Threshold Adjustment." *Journal of Business and Economic Statistics* 19(2): 166-176.

Goodwin, B.K. 2006. "Spatial and Vertical Price Transmission in Meat Markets." Paper presented at Market Integration and Vertical and Spatial Price Transmission in Agricultural Markets Workshop, Lexington KY.

Goodwin, B.K., and D.C. Harper. 2000. "Price Transmission, Threshold Behavior, and Asymmetric Adjustment in the U.S. Pork Sector." *Journal of Agricultural and Applied Economics* 32(3):543-553.

Goodwin, B.K, and M.T. Holt. 1999. "Price Transmission and Asymmetric Adjustment in the U.S. Beef Sector." *American Journal of Agricultural Economics* 81:630-637.

Hansen, B.E. 1999. "Threshold Effects in Non-Dynamic Panels: Estimation, Testing and Inference." *Journal of Econometrics* 92(2):345-368.

Hansen, B.E., and B. Seo. 2002. "Testing for Two-Regime Threshold Cointegration in Vector Error-Correction Models." *Journal of Econometrics* 110: 293-318.

Hassouneh, I., S. von Cramon-Taubadel, T. Serra, and J. M. Gil. 2012. "Recent Developments in the Econometric Analysis of Price Transmissions." Working Paper, TRANSFOP, No. 2.

Ihle, R., and S. von Cramon-Taubadel. 2008. "A Comparison of Threshold Cointegration and Markov-Switching Vector Error Correction Models in Price

Transmission Analysis." Paper presented at the NCCC-134 conference, St. Louis, Missouri.

Johansen, S. 1995. *Likelihood Based Inference in Cointegrated Vector Autoregressive Model*, Oxford, U.K.: Oxford Printing Press.

Karantininis, K., K. Katrakylidis, and M. Persson. 2011. "Price Transmission in the Swedish Pork Chain: Asymmetric non linear ARDL." Paper presented at the EAAE meeting, Switzerland, August 30 to September 2.

Kimmel, S. 2009. "Why Prices Rise Faster than they Fall." United States Department of Justice *Economic Analysis Group Discussion Papers,* EAG 09-4. http://www.justice.gov/atr/public/eag/248396.pdf.

Kinnucan, H.W., and O.D. Forker. 1987. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products." *American Journal of Agricultural Economics* 69(2): 285-292.

Kwiatkowski, D., P.C.B. Philips, P. Schmidt, and Y. Shin. 1992. "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We that Economic Time Series Have a Unit Root?" *Journal of Econometrics* 54: (159-278).

Lee, J. and M.I. Gomez. 2012. "Impacts of the End of the Coffee Export Quota System on International-to-Retail Price Transmission." *Journal of Agricultural Economics*.

Livestock Marketing Information Center. 1987-1999. Beef Retail Price Series. Compiled from United States Department of Agriculture Economic Research Service and Bureau of Labor Statistics reports.

Livestock Marketing Information Center. 2001-2012. Boxed Beef Cutout Value, Choice 600-900 pound carcass. Compiled from United States Department of Agriculture Agricultural Marketing Service reports.

Livestock Marketing Information Center. 1999-2001. Boxed Beef Cutout Value, Choice 600-750 pound carcass. Compiled from United States Department of Agriculture Agricultural Marketing Service reports.

Livestock Marketing Information Center. 1987-1999. Boxed Beef Cutout Value, Choice 550-700 pound carcass. Compiled from United States Department of Agriculture Agricultural Marketing Service reports.

Livestock Marketing Information Center. 1987-2012. Oklahoma City Feeder Cattle Auction Prices, 700-800 pound steers. Compiled from United States Department of Agriculture Agricultural Marketing Service reports.

Livestock Marketing Information Center. 1987-2012. Kansas Feedlot Sales, Choice 2-3, 1000-1100 pounds. Compiled from United States Department of Agriculture Agricultural Marketing Service reports.

Livestock Marketing Information Center. 1987-2012. National Corn Price Averages. Compiled from United States Department of Agriculture National Agricultural Statistics Service reports.

Maddala, G.S., and I.M. Kim. 1998. *Unit Roots, Cointegration, and Structural Change*, 1st ed. Cambridge, U.K.: Cambridge University Press.

McCorriston, S., C.W. Morgan, and A.J. Rayner. 2001. "Price Transmission: the Interaction between Market Power and Returns to Scale." *European Review of Agricultural Economics* 28(2): 143-159.

Meyer, J. and S. von Cramon-Taubadel. 2004. "Asymmetric Price Transmission: A Survey." *Journal of Agricultural Economics* 55(3): 581-611.

Ning. Z. 2012. "Analysis of Lumber Price Transmission in the United States." MS thesis, Mississippi State University.

Peltzman, S. 2000. "Prices Rise Faster than They Fall." *Journal of Political Economy* 108(3): 466-502.

Perron, P. 1989. "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis." *Econometrica* 57(6): 1361-1401.

Potter, S.M. 1995. "A Nonlinear Approach to US GNP." *Journal of Applied Econometrics* 10: 109-125.

Schroeder, T.C., S. Grunewald, and C. E. Ward. 2002. "Mandatory Price Reporting in Fed Cattle Markets: Motivations and Implications." Paper presented at the Council on Food, Agricultural, and Resource Economics (C-FARE) Annual Symposium, Washington D.C., November 6.

Serra, T. and B. K. Goodwin. 2003. "Price Transmission and Asymmetric Adjustment in the Spanish Dairy Sector." *Applied Economics* 35(18): 1889-1899.

Stigler, M. 2012. "Threshold Cointegration: Overview and Implementation in R." CRAN packages. http://www.cran.r-project.org/web/packages.

Tong, H. 1983. *Threshold Models in Non-linear Time Series Analysis*. New York: Spring-Verlag.

Tsay, R.S. 1989. "Testing and Modeling Threshold Autoregressive Processes." *Journal of the American Statistical Association* 84(405):231-240.

Vavra, P., and B.K. Goodwin. 2005. "Analysis of Price Transmission Along the Food Chain." Working paper, OECD Food, Agriculture and Fisheries, No. 3.

Von Cramon-Taubadel, S., and J.P. Loy. 1996. "Price Asymmetry in the International Wheat Market: Comment." *Canadian Journal of Agricultural Economics* 44: (311-317).

Wachenheim, C.J., and E.A. DeVuyst. 2001. "Strategic Response to Mandatory Reporting Legislation in the U.S. Livestock and Meat Industries: Are Collusive Opportunities Enhanced?" *Agribusiness* 17(2): 177-195.

Ward, C.E. 2006. "An Assessment of the Livestock Mandatory Reporting Act." Paper presented at NCCC-134 Conference, St. Louis MO.

Ward, C.E. 2010. "Economics of Competition in the U.S. Livestock Industry." Dept. Agr. Econ, Oklahoma State University. Working paper, Dept. of Agr. Econ., Oklahoma State University, Stillwater.

Ward, R.W., W. Moon, and S. Medina. 2002. "Measuring the Impact of Generic Promotions of U.S. Beef: Application of Double-Hurdle and Time Series Models." *International Food and Agribusiness Management Review* 4: 361-371.

Wohlgenant, M.K. 2006. "Retail-to-Farm Transmission of Generic Advertising Effects." *Choices*, 2nd quarter, 21(2).

Zappata, H.O., and W.M. Gauthier. 2003. "Threshold Models in Theory and Practice." Paper presented at the Southern Agricultural Economics Association annual meeting, Mobile AL, February 1-5.

APPENDIX

Table 1. Descriptive Statistics of Data, 1987-2012

Variable	Mean	Standard Deviation	Minimum	Maximum
Pre-LMRA (n=172)				
Fed Cattle Price (FP)	70.43	6.02	58.12	82.51
Boxed Beef Price (WP)	111.56	8.62	95.34	129.78
Retail Price (RP)	279.85	19.10	229.60	343.20
Diesel PPI (EP)	62.88	13.99	38.10	110.80
Weekly Earnings (WR)	243.49	8.76	224.48	265.05
Corn Price (CP)	2.32	0.51	1.42	4.43
Feeder Cattle Price (FC)	79.20	8.63	54.03	93.43
Post-LMRA (n=140)				
Fed Cattle Price (FP)	90.57	15.74	63.20	126.34
Boxed Beef Price (WP)	149.51	21.71	109.88	197.24
Retail Price (RP)	415.21	48.85	325.80	515.20
Diesel PPI (EP)	204.18	91.80	56.20	431.90
Weekly Earnings (WR)	242.25	8.33	222.38	262.39
Corn Price (CP)	3.50	1.60	1.76	7.63
Feeder Cattle Price (FC)	108.58	19.11	77.89	157.79

Table 2. Integration Tests of Price Series, Pre-LMRA Implementation

Test	Hypothesis	Model	Fed Cattle (FP)	Boxed Beef (WP)	Retail (RP)
		Level Data (n=172)			
ADF	$H_0 : I(1)$	No Intercept	0.12	0.50	2.05
		Intercept	-3.00*	-2.66	-0.68
		Trend	-3.39	-2.68	-1.39
PP	$H_0 : I(1)$	No Intercept	0.23	0.47	2.23
		Intercept	-3.03*	-2.80	-0.33
		Trend	-3.39	-2.81	-1.05
KPSS	$H_0 : I(0)$	Intercept	1.13*	0.48*	1.81*
		Trend	0.32*	0.35*	0.43*
		First Differenced Data			
ADF	$H_0 : I(1)$	No Intercept	-9.02*	-9.93*	-9.81*
		Intercept	-8.99*	-9.94*	-10.12*
		Trend	-8.97*	-9.91*	-10.10*
PP	$H_0 : I(1)$	No Intercept	-9.41*	-10.44*	-9.80*
		Intercept	-9.39*	-10.43*	-10.10*
		Trend	-9.36*	-10.4*	-10.08*
KPSS	$H_0 : I(0)$	Intercept	0.08	0.10	0.25
		Trend	0.08	0.10	0.24*

Note:

ADF test values are reported varying on optimal lag lengths determined by AIC/SBC.

KPSS test values are reported for a lag length of 4.

ADF critical values for no intercept, intercept, and trend are -1.95, -2.89, and -3.45, respectively.

PP critical values for no intercept, intercept, and trend are -1.95, -2.89, and -3.45, respectively.

KPSS critical values for intercept and trend are 0.463 and 0.146, respectively.

* Indicates significance at the 5% level.

Table 3. Integration Tests of Price Series, Post-LMRA Implementation

Test	Hypothesis	Model	Fed Cattle (FP)	Boxed Beef (WP)	Retail (RP)
		Level Data (n=140)			
ADF	$H_0 : I(1)$	No Intercept	1.38	1.19	1.38
		Intercept	-0.43	-0.84	-0.69
		Trend	-2.02	-2.33	-2.87
PP	$H_0 : I(1)$	No Intercept	0.86	0.54	1.68
		Intercept	-0.90	-1.52	-0.53
		Trend	-2.78	-3.50*	-2.49
KPSS	$H_0 : I(0)$	Intercept	2.05*	1.98*	2.40*
		Trend	0.27*	0.24*	0.20*
		First Differenced Data			
ADF	$H_0 : I(1)$	No Intercept	-8.41*	-9.32*	-7.03*
		Intercept	-8.58*	-9.33*	-7.35*
		Trend	-8.59*	-9.30*	-7.33*
PP	$H_0 : I(1)$	No Intercept	-8.00*	-9.25*	-9.30*
		Intercept	-8.04*	-9.26*	-9.45*
		Trend	-8.03*	-9.23*	-9.43*
KPSS	$H_0 : I(0)$	Intercept	0.09	0.07	0.07
		Trend	0.04	0.03	0.05

Note:

ADF test values are reported varying on optimal lag lengths determined by AIC/SBC.

KPSS test values are reported for a lag length of 4.

ADF critical values for no intercept, intercept, and trend are -1.95, -2.88, and -3.43, respectively.

PP critical values for no intercept, intercept, and trend are -1.95, -2.88, and -3.43, respectively.

KPSS critical values for intercept and trend are 0.463 and 0.146, respectively.

* Indicates significance at the 5% level.

Table 4. Tests of Co-integration, level data

Pair of Prices	H_0:r	Trace	λ_{max}
	Pre-LMRA (n=172)		
FP-WP (1)	0	24.35*	16.24*
	1	8.11	8.12
WP-RP (2)	0	16.70*	16.33*
	1	0.37	0.37
FP-RP (1)	0	23.82*	21.70*
	1	2.12	2.12
	Post-LMRA (n=140)		
FP-WP (5)	0	22.27*	22.24*
	1	0.03	3.22
WP-RP (3)	0	20.58*	20.33*
	1	0.26	0.26
FP-RP (2)	0	25.27*	17.74*
	1	3.73	0.30

Note: r is the number of cointegrating vectors.

*5% critical value levels (by Enders 2004) were used.

All numbers are from non-restricted models.

Lags are in parentheses.

Trace hypothesis:

H_0: # cointegrating vectors $\leq$ r , H_A: cointegrating vectors > r

λ_{max} hypothesis:

H_0: # cointegrating vectors = r , H_A: cointegrating vectors = r +1

Table 5. Threshold Testing Results for First Differenced Residuals

Test	Period	Retail	Wholesale	Farm
Optimal Lags	Pre-LMRA	6≠	12	3
	Post-LMRA	5	10	5
Delay Parameters	Pre-LMRA	3φ	2	2
	Post-LMRA	4	3	4
Tsay Test	Pre-LMRA	2.53*	1.61*	2.60*
		(0.02)†	(0.02)	(0.02)
	Post-LMRA	2.92*	1.93*	1.92*
		(0.001)	(0.006)	(0.05)
Hansen Test	Pre-LMRA	18.22*	62.49*	17.86*
		(0.02)†	(0.0)	(0.01)
	Post-LMRA	34.62*	54.71*	23.32*
		(0.01)	(0.00)	(0.03)
Threshold	Pre-LMRA	1.831	2.125	3.461
		(67.86%)‡	(83.65%)	(89.39%)
	Post-LMRA	1.955	4.133	1.935
		(58.96%)	(67.44%)	(60.45%)

Note:

≠: Optimal lags were selected based off of AIC criteria.

φ: the delay parameter is selected such that the max TAR-F statistic is chosen.

†: indicates standard errors.

‡: indicates percentage of observations which fall in the inside regime.

*: indicates significance at the 5% level.

Table 6. Estimation Results for Retail-Wholesale Relationship, Symmetric Threshold Error Correction Model

Variables	Pre-LMRA n=172 Parameter Estimates	Pre-LMRA n=172 Standard Error	Post-LMRA n=140 Parameter Estimates	Post-LMRA n=140 Standard Error
Retail Equation:				
Constant	-0.304	(0.428	1.318	1.073
ε_{t-1}^{OUT}	0.089*	0.036	-0.09	0.068
ε_{t-1}^{IN}	-0.079*	0.033	-0.14*	0.063
ΔRP_{t-1}	-0.079	0.089	-0.152	0.088
ΔWP_{t-1}	0.047	0.082	-0.062	0.100
ΔEP_{t-1}	0.026	0.046	0.03	0.032
Wholesale Equation:				
Constant	0.586	0.405	0.771	0.838
ε_{t-1}^{OUT}	-0.071*	0.034	-0.177*	0.053
ε_{t-1}^{IN}	-0.022	0.031	-0.179*	0.049
ΔWP_{t-1}	0.264*	0.078	-0.018	0.081
ΔRP_{t-1}	-0.143	0.084	-0.022	0.071
ΔWR_{t-1}	0.022	0.048	0.037	0.102

Results derived via SUR.

* Indicates significance at the 5% level.

Table 7. Estimation Results for Wholesale-Farm Relationship, Symmetric Threshold Error Correction Model

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Wholesale Equation:				
Constant	-0.246	0.348	-0.045	0.696
ε_{t-1}^{OUT}	0.136	0.092	0.495*	0.158
ε_{t-1}^{IN}	-0.17	0.139	0.043	0.193
ΔWP_{t-1}	0.163	0.083	0.021	0.086
ΔFP_{t-1}	-0.048	0.128	-0.247	0.164
ΔWR_{t-1}	0.077*	0.037	-0.014	0.075
Farm Equation:				
Constant	-0.364	0.23	0.167	0.375
ε_{t-1}^{OUT}	0.047	0.061	0.025	0.085
ε_{t-1}^{IN}	-0.305*	0.092	-0.178	0.105
ΔFP_{t-1}	-0.288*	0.078	-0.148	0.086
ΔWP_{t-1}	0.101	0.053	0.079	0.044
ΔFC_{t-1}	0.175*	0.053	-0.069	0.055

Results derived via SUR.

* Indicates significance at the 5% level.

Table 8. Estimation Results for Retail-Farm Relationship, Symmetric Threshold Error Correction Model

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
Constant	-0.36	0.352	1.446	1.066
ε_{t-1}^{OUT}	0.109*	0.027	-0.102	0.066
ε_{t-1}^{IN}	-0.044	0.025	-0.105	0.078
ΔRP_{t-1}	-0.051	0.082	-0.054	0.094
ΔFP_{t-1}	-0.051	0.112	-0.252	0.204
ΔEP_{t-1}	0.011	0.046	0.015	0.032
Farm Equation:				
Constant	-0.017	0.243	0.181	0.449
ε_{t-1}^{OUT}	-0.003	0.018	-0.078*	0.027
ε_{t-1}^{IN}	-0.022	0.017	-0.115*	0.032
ΔFP_{t-1}	-0.229*	0.077	-0.140	0.084
ΔRP_{t-1}	-0.028	0.055	0.067	0.039
ΔCP_{t-1}	-0.086	1.251	0.473	1.231

Results derived via SUR.

* Indicates significance at the 5% level.

Table 9. Estimation Results for Retail-Wholesale Relationship, Asymmetric Threshold Error Correction Model

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
Constant	-0.252	0.688	0.830	1.468
ε_{t-1}^{OUT}	0.080*	0.037	-0.078	0.068
ε_{t-1}^{IN}	-0.075*	0.033	-0.141*	0.062
$\Delta^{+} RP_{t-1}$	-0.082	0.157	0.085	0.135
$\Delta^{-} RP_{t-1}$	-0.066	0.195	-0.51*	0.195
$\Delta^{+} WP_{t-1}$	0.162	0.173	-0.369*	0.184
$\Delta^{-} WP_{t-1}$	-0.045	0.149	0.285	0.193
$\Delta^{+} EP_{t-1}$	-0.028	0.073	0.065	0.062
$\Delta^{-} EP_{t-1}$	0.104	0.085	-0.003	0.050
Wholesale Equation:				
Constant	0.068	0.648	0.135	1.400
ε_{t-1}^{OUT}	-0.068*	0.035	-0.177*	0.054
ε_{t-1}^{IN}	-0.023	0.032	-0.182*	0.050
$\Delta^{+} WP_{t-1}$	0.197	0.152	0.113	0.148
$\Delta^{-} WP_{t-1}$	0.327*	0.145	-0.170	0.162
$\Delta^{+} FP_{t-1}$	-0.134	0.146	-0.070	0.112
$\Delta^{-} FP_{t-1}$	-0.143	0.183	0.048	0.163
$\Delta^{+} WR_{t-1}$	0.035	0.108	0.122	0.241
$\Delta^{-} WR_{t-1}$	0.013	0.085	0.007	0.175

Results derived via SUR.

*indicates significance 5% level.

Table 10. Estimation Results for Wholesale-Farm Relationship, Asymmetric Threshold Error Correction Model

Variables	Pre-LMRA n=172		Post-LMRA n=140	
	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Wholesale Equation:				
Constant	-0.250	0.501	0.132	1.058
ε_{t-1}^{OUT}	0.147	0.094	0.491*	0.162
ε_{t-1}^{IN}	-0.178	0.141	0.035	0.197
$\Delta^{+} WP_{t-1}$	0.099	0.128	0.014	0.137
$\Delta^{-} WP_{t-1}$	0.238	0.148	0.016	0.157
$\Delta^{-} FP_{t-1}$	0.018	0.203	-0.280	0.278
$\Delta^{+} FP_{t-1}$	-0.127	0.206	-0.178	0.291
$\Delta^{+} WR_{t-1}$	0.084	0.081	-0.019	0.178
$\Delta^{-} WR_{t-1}$	0.067	0.064	0.005	0.137
Farm Equation:				
Constant	-0.382	0.317	0.018	0.492
ε_{t-1}^{OUT}	0.046	0.063	0.04	0.085
ε_{t-1}^{IN}	-0.303*	0.093	-0.186	0.105
$\Delta^{+} FP_{t-1}$	-0.287*	0.133	0.039	0.140
$\Delta^{-} FP_{t-1}$	-0.277*	0.132	-0.381*	0.148
$\Delta^{+} WP_{t-1}$	0.096	0.090	-0.027	0.073
$\Delta^{-} WP_{t-1}$	0.094	0.091	0.216*	0.083
$\Delta^{+} FC_{t-1}$	0.195*	0.097	-0.008	0.106
$\Delta^{-} FC_{t-1}$	0.162	0.098	-0.110	0.092

Results derived via SUR.

*indicates significance 5% level.

Table 11. Estimation Results for Retail-Farm Relationship, Asymmetric Threshold Error Correction Model

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
Constant	0.114	0.644	-1.567	1.390
ε_{t-1}^{OUT}	0.111*	0.027	-0.193*	0.059
ε_{t-1}^{IN}	-0.040	0.025	-0.27*	0.070
$\Delta^{+} RP_{t-1}$	-0.060	0.145	0.259*	0.125
$\Delta^{-} RP_{t-1}$	-0.026	0.184	-0.452*	0.171
$\Delta^{+} FP_{t-1}$	-0.076	0.236	-0.49	0.331
$\Delta^{-} FP_{t-1}$	-0.034	0.200	-0.104	0.311
$\Delta^{+} EP_{t-1}$	-0.089	0.073	0.092	0.052
$\Delta^{-} EP_{t-1}$	0.133	0.083	-0.071	0.044
Farm Equation:				
Constant	0.382	0.421	-0.186	0.770
ε_{t-1}^{OUT}	-0.0003	0.019	-0.008	0.032
ε_{t-1}^{IN}	-0.022	0.017	-0.021	0.038
$\Delta^{+} FP_{t-1}$	-0.355*	0.156	-0.241	0.178
$\Delta^{-} FP_{t-1}$	-0.123	0.139	-0.124	0.168
$\Delta^{+} RP_{t-1}$	-0.119	0.094	0.141*	0.067
$\Delta^{-} RP_{t-1}$	0.099	0.127	-0.064	0.093
$\Delta^{+} CP_{t-1}$	1.033	2.478	1.424	1.944
$\Delta^{-} CP_{t-1}$	-0.426	1.827	0.088	2.784

Results derived via SUR.

*indicates significance 5% level.

Table 12. Hypothesis Tests of Short-Run Asymmetries for the Retail-Wholesale Price Relationship

Test	Pre-LMRA	Post-LMRA
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ †	6.79**	0.33
$\Delta^+ RP_{t-1} = \Delta^- RP_{t-1}$	0.00	4.63**
$\Delta^+ WP_{t-1} = \Delta^- WP_{t-1}$	0.59	4.18**
$\Delta^+ EP_{t-1} = \Delta^- EP_{t-1}$	1.09	0.53
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ ‡	0.63	0.00
$\Delta^+ WP_{t-1} = \Delta^- WP_{t-1}$	0.45	0.00
$\Delta^+ RP_{t-1} = \Delta^- RP_{t-1}$	0.23	0.05
$\Delta^+ WR_{t-1} = \Delta^- WR_{t-1}$	0.02	0.01

* and ** indicate significance at the 10 and 5% levels, respectively.

† and ‡ refer to equations 13 and 14, respectively.
F statistics are reported.

Table 13. Hypothesis Tests of Short-Run Asymmetries for the Wholesale-Farm Price Relationship

Test	Pre-LMRA	Post-LMRA
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ †	3.06*	2.89*
$\Delta^+ WP_{t-1} = \Delta^- WP_{t-1}$	0.45	0.00
$\Delta^+ FP_{t-1} = \Delta^- FP_{t-1}$	0.23	0.05
$\Delta^+ WR_{t-1} = \Delta^- WR_{t-1}$	0.02	0.01
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ ‡	8.03**	2.50
$\Delta^+ FP_{t-1} = \Delta^- FP_{t-1}$	0.00	3.74*
$\Delta^+ WP_{t-1} = \Delta^- WP_{t-1}$	0.00	4.06**
$\Delta^+ FC_{t-1} = \Delta^- FC_{t-1}$	0.05	0.43

* and ** indicate significance at the 10 and 5% levels, respectively.
† and ‡ refer to equations 14 and 15, respectively.
F statistics are reported.

Table 14. Hypothesis Tests of Short-Run Asymmetries for the Retail-Farm Price Relationship

Test	Pre-LMRA	Post-LMRA
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ †	12.96**	0.49
$\Delta^{+} RP_{t-1} = \Delta^{-} RP_{t-1}$	0.01	8.57**
$\Delta^{+} FP_{t-1} = \Delta^{-} FP_{t-1}$	0.03	0.53
$\Delta^{+} EP_{t-1} = \Delta^{-} EP_{t-1}$	3.14*	4.67**
$\varepsilon_{t-1}^{OUT} = \varepsilon_{t-1}^{IN}$ ‡	0.55	0.05
$\Delta^{+} FP_{t-1} = \Delta^{-} FP_{t-1}$	0.85	0.16
$\Delta^{+} RP_{t-1} = \Delta^{-} RP_{t-1}$	1.33	2.42
$\Delta^{+} CP_{t-1} = \Delta^{-} CP_{t-1}$	0.18	0.13

* and ** indicate significance at the 10 and 5% levels, respectively.

† and ‡ refer to equations 16 and 17, respectively.

F statistics are reported.

Table 15. Estimation Results for Retail-Wholesale Relationship, Standard Error Correction Model (Symmetric Representation)

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
ΔRP_t	-0.021	(0.006)	-0.078	(0.026)
ΔWP_t	0.024	(0.007)	0.229	(0.075)
ΔEP_t	0.057	(0.016)	-0.007	(0.002)
ΔRP_{t-1}	0.022	(0.070)	0.010	(0.076)
ΔWP_{t-1}	0.476*	(0.068)	0.452*	(0.094)
ΔEP_{t-1}	-0.043	(0.041)	0.010	(0.026)
Wholesale Equation:				
ΔWP_t	-0.081	(0.031)	-0.268	(0.074)
ΔRP_t	0.013	(0.005)	0.108	(0.030)
ΔWR_t	0.022	(0.008)	-0.022	(0.006)
ΔWP_{t-1}	0.296*	(0.077)	0.412*	(0.093)
ΔRP_{t-1}	-0.072	(0.082)	0.003	(0.074)
ΔWR_{t-1}	-0.148*	(0.050)	-0.161	(0.107)

* Indicates significance at the 5% level.

Table 16. Estimation Results for Wholesale-Farm Relationship, Standard Error Correction Model (Symmetric Representation)

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Wholesale Equation:				
ΔWP_t	0.009	(0.039)	-0.471	(0.106)
ΔFP_t	-0.017	(0.078)	0.643	(0.145)
ΔWR_t	0.001	(0.005)	0.050	(0.011)
ΔWP_{t-1}	-0.170	(0.111)	0.149	(0.122)
ΔFP_{t-1}	0.770*	(0.170)	0.419	(0.228)
ΔWR_{t-1}	-0.069	(0.051)	-0.096	(0.101)
Farm Equation:				
ΔFP_t	-0.052	(0.019)	-0.147	(0.066)
ΔWP_t	-0.023	(0.008)	0.035	(0.016)
ΔFC_t	0.078	(0.028)	0.075	(0.034)
ΔFP_{t-1}	0.549*	(0.107)	0.568*	(0.122)
ΔWP_{t-1}	-0.188*	(0.073)	-0.064	(0.062)
ΔFC_{t-1}	-0.015	(0.070)	-0.112	(0.078)

* Indicates significance at the 5% level.

Table 17. Estimation Results for Retail-Farm Relationship, Standard Error Correction Model (Symmetric Representation)

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
ΔRP_t	-0.016	(0.006)	-0.039	(0.018)
ΔFP_t	0.020	(0.007)	0.205	(0.098)
ΔEP_t	0.051	(0.018)	-0.012	(0.006)
ΔRP_{t-1}	0.121	(0.068)	-0.044	(0.075)
ΔFP_{t-1}	0.648*	(0.100)	1.198*	(0.171)
ΔEP_{t-1}	-0.051	(0.042)	-0.004	(0.026)
Farm Equation:				
ΔFP_t	0.000	(0.008)	-0.145	(0.051)
ΔRP_t	0.000	(0.000)	0.027	(0.010)
ΔCP_t	-0.004	(0.263)	0.471	(0.166)
ΔFP_{t-1}	0.378*	(0.072)	0.545*	(0.086)
ΔRP_{t-1}	-0.166*	(0.050)	-0.093*	(0.038)
ΔCP_{t-1}	2.236	(1.190)	1.005	(1.137)

* Indicates significance at the 5% level.

Table 18. Estimation Results for Retail-Wholesale Relationship, Standard Error Correction Model (Asymmetric Representation)

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
$\Delta^+ RP_t$	-0.124	(0.029)	-0.433	(0.054)
$\Delta^- RP_t$	-0.419	(0.098)	-0.707	(0.088)
$\Delta^+ WP_t$	0.274	(0.064)	0.761	(0.095)
$\Delta^- WP_t$	0.458	(0.107)	0.786	(0.098)
$\Delta^+ EP_t$	-0.005	(0.001)	-0.0556	(0.007)
$\Delta^- EP_t$	0.005	(0.001)	-0.020	(0.003)
$\Delta^+ RP_{t-1}$	-0.449*	(0.071)	-0.262*	(0.071)
$\Delta^- RP_{t-1}$	0.349*	(0.106)	0.366*	(0.095)
$\Delta^+ WP_{t-1}$	0.128	(0.093)	-0.141	(0.113)
$\Delta^- WP_{t-1}$	-0.110	(0.104)	-0.509*	(0.116)
$\Delta^+ EP_{t-1}$	-0.012	(0.047)	0.015	(0.031)
$\Delta^- EP_{t-1}$	0.030	(0.049)	0.022	(0.026)
Wholesale Equation:				
$\Delta^+ WP_t$	-0.095	(0.045)	-0.392	(0.080)
$\Delta^- WP_t$	-0.197	(0.093)	-0.380	(0.077)
$\Delta^+ FP_t$	0.109	(0.052)	0.234	(0.048)
$\Delta^- FP_t$	0.144	(0.068)	0.364	(0.074)
$\Delta^+ WR_t$	-0.070	(0.033)	-0.010	(0.002)
$\Delta^- WR_t$	0.015	(0.007)	-0.106	(0.021)
$\Delta^+ WP_{t-1}$	-0.344*	(0.085)	-0.049	(0.094)
$\Delta^- WP_{t-1}$	0.276*	(0.093)	0.320*	(0.097)
$\Delta^+ FP_{t-1}$	-0.247*	(0.068)	-0.226*	(0.061)
$\Delta^- FP_{t-1}$	0.065	(0.095)	0.012	(0.083)
$\Delta^+ WR_{t-1}$	0.003	(0.054)	-0.015	(0.113)
$\Delta^- WR_{t-1}$	-0.000	(0.043)	0.093	(0.095)

*indicates significance 5% level.

Table 19. Estimation Results for Wholesale-Farm Relationship, Standard Error Correction Model (Asymmetric Representation)

	Pre-LMRA n=172		Post-LMRA n=140	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Wholesale Equation:				
$\Delta^+ WP_t$	-0.271	(0.068)	-0.326	(0.055)
$\Delta^- WP_t$	-0.434	(0.108)	-0.783	(0.133)
$\Delta^- FP_t$	0.620	(0.155)	0.140	(0.024)
$\Delta^+ FP_t$	0.233	(0.058)	1.458	(0.248)
$\Delta^+ WR_t$	-0.202	(0.050)	-0.065	(0.011)
$\Delta^- WR_t$	0.089	(0.022)	-0.364	(0.062)
$\Delta^+ WP_{t-1}$	-0.346*	(0.101)	-0.286*	(0.096)
$\Delta^- WP_{t-1}$	0.243*	(0.111)	0.381*	(0.114)
$\Delta^- FP_{t-1}$	-0.197	(0.170)	0.462*	(0.189)
$\Delta^+ FP_{t-1}$	0.024	(0.146)	-0.723*	(0.220)
$\Delta^+ WR_{t-1}$	0.066	(0.057)	0.067	(0.109)
$\Delta^- WR_{t-1}$	-0.014	(0.043)	0.244*	(0.094)
Farm Equation:				
$\Delta^+ FP_t$	0.049	(0.096)	0.071	(0.059)
$\Delta^- FP_t$	0.034	0.066)	0.154	(0.127)
$\Delta^+ WP_t$	-0.033	(0.064)	-0.048	(0.039)
$\Delta^- WP_t$	-0.038	(0.075)	-0.101	(0.083)
$\Delta^+ FC_t$	-0.004	(0.008)	-0.020	(0.017)
$\Delta^- FC_t$	0.05	(0.030)	-0.002	(0.001)
$\Delta^+ FP_{t-1}$	-0.375*	(0.110)	-0.229*	(0.110)
$\Delta^- FP_{t-1}$	0.142	(0.101)	0.083	(0.117)
$\Delta^+ WP_{t-1}$	-0.084	(0.068)	-0.030	(0.053)
$\Delta^- WP_{t-1}$	-0.043	(0.071)	0.025	(0.068)
$\Delta^+ FC_{t-1}$	-0.049	(0.064)	-0.078	(0.078)
$\Delta^- FC_{t-1}$	0.105	(0.066)	0.039	(0.063)

*indicates significance 5% level.

Table 20. Estimation Results for Retail-Farm Relationship, Standard Error Correction Model (Asymmetric Representation)

Variables	Pre-LMRA n=172 Parameter Estimates	Standard Error	Post-LMRA n=140 Parameter Estimates	Standard Error
Retail Equation:				
$\Delta^+ RP_t$	-0.524	(0.061)	-0.829	(0.088)
$\Delta^- RP_t$	-0.609	(0.071)	-0.625	(0.066)
$\Delta^+ FP_t$	0.647	(0.075)	1.698	(0.180)
$\Delta^- FP_t$	0.648	(0.076)	0.937	(0.099)
$\Delta^+ EP_t$	0.029	(0.003)	-0.016	(0.002)
$\Delta\text{-} EP_t$	-0.096	(0.011)	-0.020	(0.002)
$\Delta^+ RP_{t-1}$	-0.219*	(0.069)	-0.039	(0.076)
$\Delta^- RP_{t-1}$	0.408*	(0.092)	0.307	(0.085)
$\Delta^+ FP_{t-1}$	-0.192	(0.126)	-0.422	(0.230)
$\Delta^- FP_{t-1}$	-0.272*	(0.123)	-0.678*	(0.185)
$\Delta^+ EP_{t-1}$	-0.069	(0.418)	-0.033	(0.029)
$\Delta^- EP_{t-1}$	0.077	(0.044)	0.035	(0.024)
Farm Equation:				
$\Delta^+ FP_t$	-0.041	(0.025)	-0.017	(0.082)
$\Delta^- FP_t$	-0.112	(0.068)	-0.095	(0.045)
$\Delta^+ RP_t$	0.031	(0.019)	0.084	(0.040)
$\Delta^- RP_t$	0.088	(0.054)	0.06	(0.029)
$\Delta^+ CP_t$	0.053	(0.032)	-0.004	(0.002)
$\Delta^- CP_t$	0.601	(0.365)	0.068	(0.033)
$\Delta^+ FP_{t-1}$	-0.384*	(0.070)	-0.085	(0.102)
$\Delta^- FP_{t-1}$	0.234*	(0.081)	0.228*	(0.085)
$\Delta^+ RP_{t-1}$	-0.165*	(0.039)	-0.123*	(0.034)
$\Delta^- RP_{t-1}$	-0.23	(0.057)	0.047	(0.040)
$\Delta^+ CP_{t-1}$	0.239	(1.384)	2.469*	(0.962)
$\Delta^- CP_{t-1}$	3.033*	(1.136)	-0.284	(1.238)

*indicates significance 5% level.

Table 21. Descriptive Statistics of Truncated Data Set, 1996-2006

Variable	Mean	Standard Deviation	Minimum	Maximum
Pre-LMRA (n=65)				
Fed Cattle Price (FP)	66.56	5.02	58.12	79.50
Boxed Beef Price (WP)	108.70	9.91	95.34	130.61
Retail Price (RP)	290.00	17.65	272.00	343.80
Diesel PPI (EP)	68.32	18.19	38.10	110.80
Weekly Earnings (WR)	243.75	8.89	227.50	260.61
Corn Price (CP)	2.38	0.69	1.52	4.43
Feeder Cattle Price (FC)	76.08	9.98	54.03	93.43
Post-LMRA (n=67)				
Fed Cattle Price (FP)	80.44	9.54	63.20	100.46
Boxed Beef Price (WP)	136.27	15.76	109.88	176.06
Retail Price (RP)	379.12	33.37	325.80	431.70
Diesel PPI (EP)	135.83	57.38	56.20	264.10
Weekly Earnings (WR)	244.55	9.78	222.38	262.39
Corn Price (CP)	2.19	0.29	1.76	3.01
Feeder Cattle Price (FC)	99.26	13.94	77.89	119.67

Table 22. Integration Tests of Price Series, Pre-LMRA Implementation (Truncated Data)

Test	Hypothesis	Model	Fed Cattle (FP)	Boxed Beef (WP)	Retail (RP)
		Level Data (n=65)			
ADF	$H_0 : I(1)$	No Intercept	0.27	1.25	2.06
		Intercept	-2.63	-0.60	2.79
		Trend	-3.33	-1.88	0.85
PP	$H_0 : I(1)$	No Intercept	0.47	0.83	1.96
		Intercept	-1.63	-0.93	1.82
		Trend	-2.32	-2.44	-0.31
KPSS	$H_0 : I(0)$	Intercept	0.73*	1.19*	0.35
		Trend	0.25*	0.26*	0.12
		First Differenced Data			
ADF	$H_0 : I(1)$	No Intercept	-5.01*	-5.51*	-2.58*
		Intercept	-5.03*	-5.69*	-3.16*
		Trend	-4.97*	-5.71*	-4.10*
PP	$H_0 : I(1)$	No Intercept	-5.17*	-6.80*	-6.19*
		Intercept	-5.15*	-6.86*	-6.50*
		Trend	-5.11*	-6.85*	-7.02*
KPSS	$H_0 : I(0)$	Intercept	0.07	0.11	0.64
		Trend	0.12	0.03	0.07

Note:
ADF and PP critical values for no intercept, intercept, and trend are -1.95, -2.93, and -3.5, respectively.

KPSS critical values for intercept and trend are 0.463 and 0.146, respectively.

* Indicates significance at the 5% level.

Table 23. Integration Tests of Price Series, Post-LMRA Implementation

Test	Hypothesis	Model	Fed Cattle (FP)	Boxed Beef (WP)	Retail (RP)
		Level Data (n=67)			
ADF	H_0 : I(1)	No Intercept	0.31	0.53	0.76
		Intercept	-1.84	-1.62	-1.27
		Trend	-2.93	-1.90	-0.90
PP	H_0 : I(1)	No Intercept	0.13	-0.02	0.49
		Intercept	-1.91	-2.24	-1.27
		Trend	-2.87	-3.11	-1.51
KPSS	H_0 : I(0)	Intercept	1.22*	1.09*	1.30*
		Trend	0.22*	0.19*	0.31*
		First Differenced Data			
ADF	H_0 : I(1)	No Intercept	-6.32*	-5.00*	-4.22*
		Intercept	-6.33*	-5.06*	-4.34*
		Trend	-6.28*	-5.08*	-4.48*
PP	H_0 : I(1)	No Intercept	-5.24*	-5.80*	-6.36*
		Intercept	-5.22*	-5.77*	-6.35*
		Trend	-5.19*	-5.74*	-6.33*
KPSS	H_0 : I(0)	Intercept	0.04	0.05	0.14
		Trend	0.04	0.05	0.11

Note:
ADF and PP critical values for no intercept, intercept, and trend are -1.95, -2.93, and -3.5, respectively.

KPSS critical values for intercept and trend are 0.463 and 0.146, respectively.

* Indicates significance at the 5% level.

Table 24. Tests of Co-integration for Truncated Data Set

Pair of Prices	H_0: r	Trace	λ_{max}
Pre-LMRA (n=65)			
FP-WP (2)	0	19.43*	17.67*
	1	1.76	1.76*
WP-RP (1)	0	23.21*	22.72*
	1	0.49	0.49
FP-RP (2)	0	19.73*	17.15*
	1	2.58	2.58
Post-LMRA (n=67)			
FP-WP (2)	0	17.07*	25.89*
	1	1.52	1.69
WP-RP (5)	0	25.89*	19.05*
	1	1.69	7.44
FP-RP (2)	0	26.35*	24.20*
	1	7.31*	1.69

Note: r is the number of cointegrating vectors.
*5% critical value levels (by Enders 2004) were used.

All numbers are from non-restricted models.

Lags are in parentheses.

Table 25. Estimation Results for Retail-Wholesale Relationship (Truncated Model), Standard Error Correction Model

	Pre-LMRA n=65		Post-LMRA n=67	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
ΔRP_t	-0.088	(0.036)	-0.118	(0.041)
ΔWP_t	0.248	(0.101)	0.345	(0.120)
ΔEP_t	-0.017	(0.007)	-0.015	(0.005)
ΔRP_{t-1}	0.041	(0.117)	-0.038	(0.111)
ΔWP_{t-1}	0.294*	(0.130)	0.380*	(0.132)
ΔEP_{t-1}	-0.005	(0.083)	0.033	(0.052)
Wholesale Equation:				
ΔWP_t	-0.208	(0.096)	-0.458	(0.115)
ΔRP_t	0.064	(0.030)	0.182	(0.046)
ΔWR_t	0.015	(0.007)	-0.027	(0.007)
ΔWP_{t-1}	0.307*	(0.134)	0.651*	(0.126)
ΔRP_{t-1}	0.082	(0.124)	0.034	(0.103)
ΔWR_{t-1}	-0.213*	(0.101)	0.047	(0.158)

* Indicates significance at the 5% level.

Table 26. Estimation Results for Wholesale-Farm Relationship (Truncated Model), Standard Error Correction Model

	Pre-LMRA n=65		Post-LMRA n=67	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Wholesale Equation:				
ΔWP_t	-0.011	(0.061)	-0.515	(0.162)
ΔFP_t	0.030	(0.159)	0.819	(0.258)
ΔWR_t	-0.003	(0.016)	0.018	(0.006)
ΔWP_{t-1}	-0.130	(0.155)	0.336	(0.173)
ΔFP_{t-1}	0.812*	(0.286)	0.260	(0.336)
ΔWR_{t-1}	-0.163	(0.101)	0.097	(0.163)
Farm Equation:				
ΔFP_t	-0.071	(0.070)	-0.216	(0.169)
ΔWP_t	0.059	(0.059)	0.112	(0.087)
ΔFC_t	-0.022	(0.021)	0.022	(0.017)
ΔFP_{t-1}	0.748*	(0.160)	0.465*	(0.193)
ΔWP_{t-1}	-0.262*	(0.089)	0.015	(0.088)
ΔFC_{t-1}	-0.050	(0.097)	-0.058	(0.127)

* Indicates significance at the 5% level.

Table 27. Estimation Results for Retail-Farm Relationship (Truncated Model), Standard Error Correction Model

	Pre-LMRA n=5		Post-LMRA n=67	
Variables	Parameter Estimates	Standard Error	Parameter Estimates	Standard Error
Retail Equation:				
ΔRP_t	-0.044	(0.037)	-0.151	(0.042)
ΔFP_t	0.198	(0.168)	0.766	(0.212)
ΔEP_t	-0.007	(0.006)	-0.031	(0.009)
ΔRP_{t-1}	0.173	(0.109)	-0.227*	(0.107)
ΔFP_{t-1}	0.703*	(0.229)	1.111*	(0.236)
ΔEP_{t-1}	-0.023	(0.088)	0.061	(0.047)
Farm Equation:				
ΔFP_t	-0.291	(0.086)	-0.248	(0.109)
ΔRP_t	0.065	(0.019)	0.059	(0.026)
ΔCP_t	0.248	(0.073)	-1.136	(0.499)
ΔFP_{t-1}	0.608*	(0.116)	0.748*	(0.126)
ΔRP_{t-1}	-0.063	(0.055)	-0.142*	(0.052)
ΔCP_{t-1}	0.764	(1.299)	-1.487	(3.329)

* Indicates significance at the 5% level.

Figure 1. Beef Prices: 1987-2012

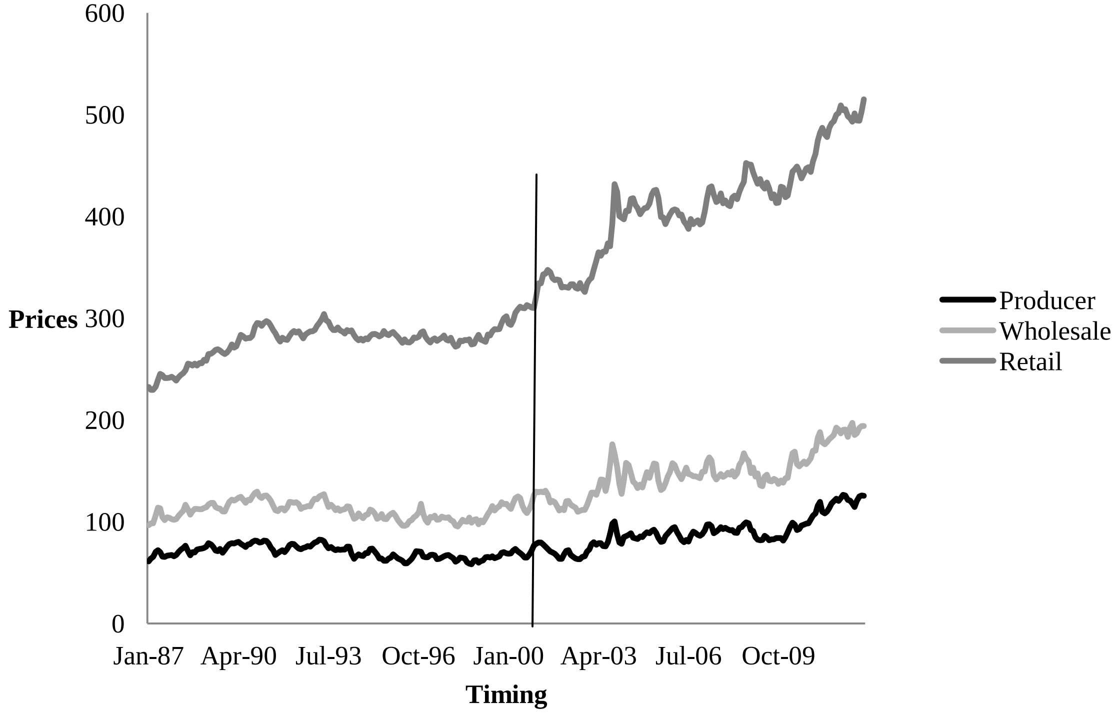


Figure 2. Diesel PPI (1982 Base Year): 1987-2012

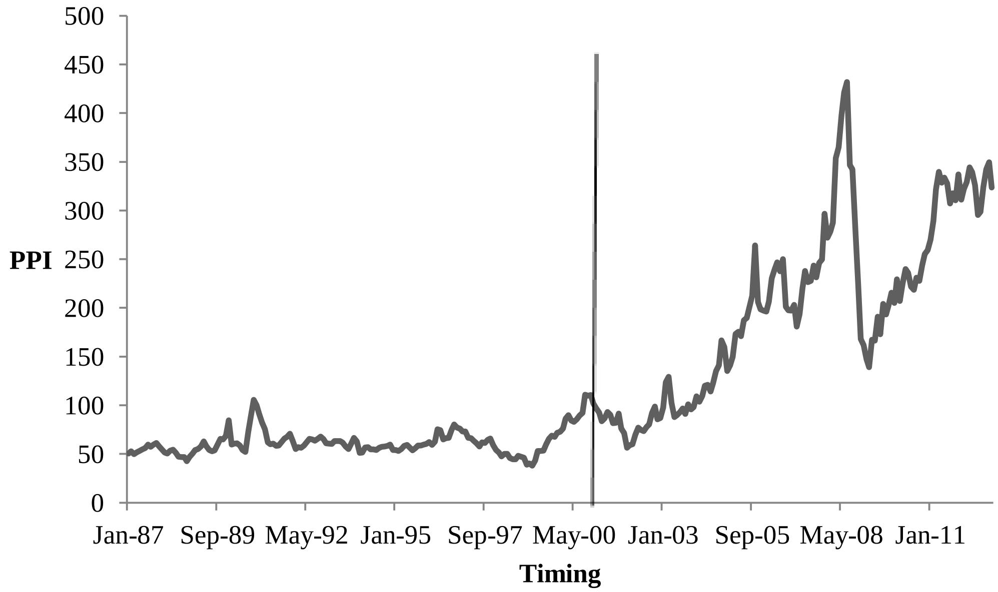


Figure 3. Average Earnings per Week for Animal Slaughtering and Processing: 1987-2012 (1982-84 dollars)

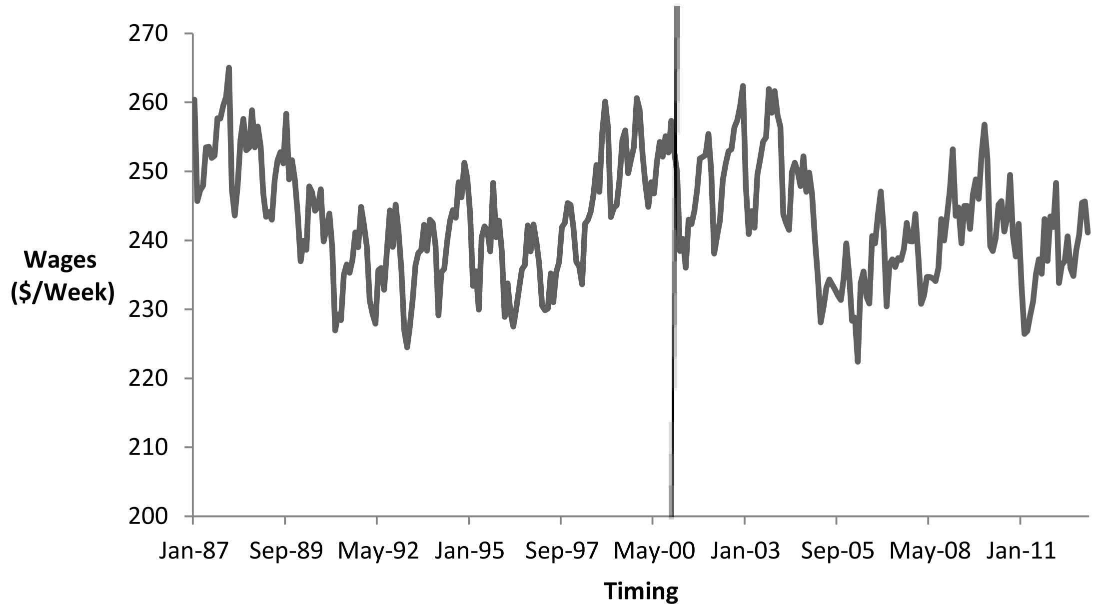


Figure 4. Corn Prices: 1987-2012

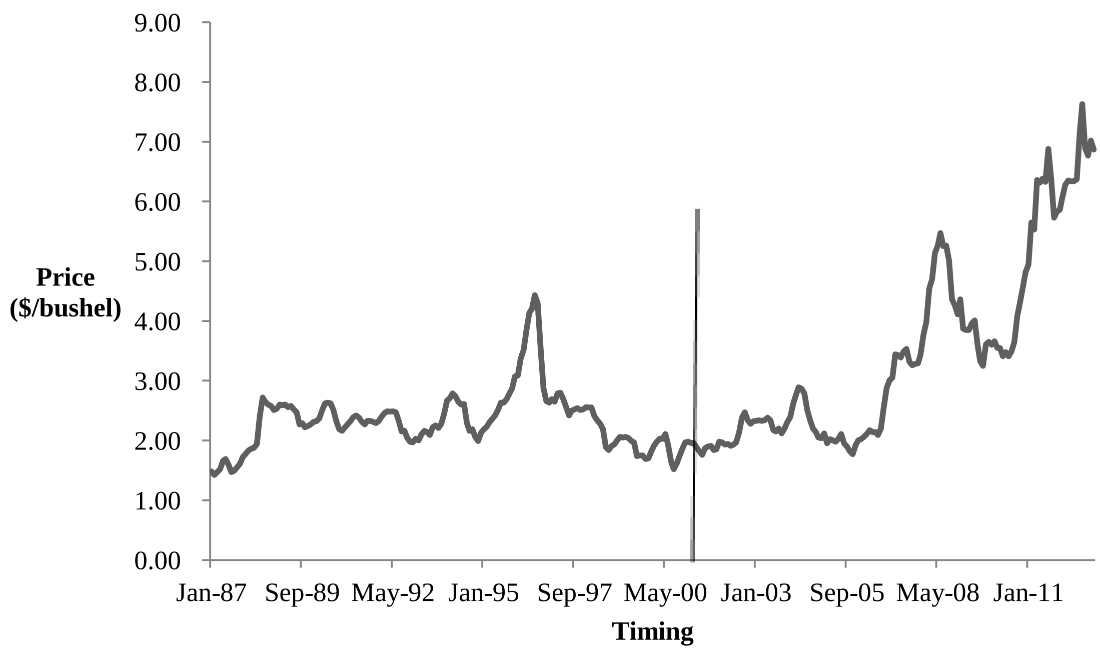
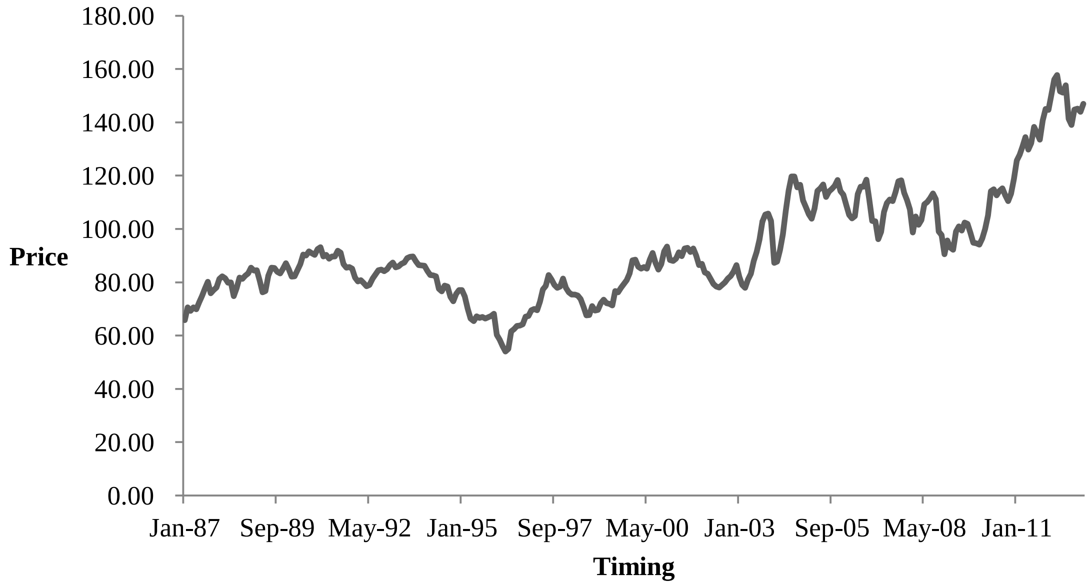


Figure 5. OKC Feeder Cattle Auction Prices:1987-2012.



VITA

Johnna Lynn Rushin

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF THE LIVESTOCK MANDATORY REPORTING ACT ON PRICE TRANSMISSION WITHIN THE BEEF MARKETING CHANNEL

Major Field: Agricultural Economics

Biographical:

Education:
Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in May, 2013.

Completed the requirements for the Bachelor of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in 2011.

Experience:
Research Assistant, Oklahoma State University, August 2011 to May 2013.

Professional Memberships:
Graduate and Professional Student Government Association, August 2011 to May 2013; Agricultural Economics Graduate Student Association, August 2011 to May 2013; Agricultural and Applied Economics Association, 2008 to 2012.