# Quantifying Weekly Beef Production using Monthly Feeder Cattle Placements

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

WITH A MAJOR IN APPLIED ECONOMETRICS

In the Graduate College

THE UNIVERSITY OF ARIZONA

2015

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona.

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Professor's Signature Date

ACKNOWLEDGEMENTS

This thesis could not have been possible without the support of the Agricultural and Resource Economics Department. The direct or indirect contributions of the faculty, staff, alumni, and students have helped drive me to the completion of my degree and more importantly, bettering me as a person. I would like to acknowledge and thank everyone that has helped me in this process.

My deepest gratitude goes to Dr. Russell Tronstad for his friendship, intellectual encouragement, constructive criticism, financial support, and willingness to help whenever I needed it. I express my appreciation to Dr. Satheesh Aradhyula and Dr. Gary Thompson for their help and guidance in the econometrics of this project, and as excellent professors in providing me the skills to accomplish this research project. I also want to thank Dr. Dan Faulkner for his insight into the biological component of this research. Finally I want to thank Mr. Trent Teegerstrom for having supported me and guided me in my research assistantship duties.

Finally, I would like to thank my family for their constant support and encouragement in my pursuit for a graduate degree. I would also like to thank my graduate cohort, it has been a lot of fun learning and supporting one another for our two years in this program. I want to thank all the people in the department and outside for the enriching experience at the University of Arizona.

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ABSTRACT

Beginning in December 1995, USDA/NASS started reporting monthly cattle-on-feed placements for four different weight groups, to provide information regarding future slaughter numbers and beef production. The focus of this thesis is to empirically quantify relationships between monthly placements of steers and heifers into the feedlot with weekly federally inspected fed beef slaughtered. Weight of feeders when placed in the feedlot, average daily gain, quality premiums, seasonality, and other factors are used to quantify relationships between feeder placements and slaughter numbers. A comparison of the forecasting accuracy of alternative seasonal adjustment approaches is carried out in this thesis to evaluate how to best capture seasonal effects on beef production. This study will improve understanding of the cattle feeding timeline and weight gain relationships between feedlot placements, economic incentives of cattle feeding, and federally inspected fed cattle.

# CHAPTER 1: INTRODUCTION

## Background:

As of July 1, 2014, there were 95 million head of cattle in the United States with 25.8 billion pounds of beef produced, most consumed domestically. The supply chain for the beef industry is composed of various sectors, including seed stock, cow-calf, stocker, feedlots, and packer sectors. These sectors are concentrated in various regions throughout the United States. For the focus of this thesis, the feedlot and packer sectors are examined. The feedlot sector is located throughout the U.S. but the highest concentration is in the central U.S. The beef industry is vital for many economies as the ranches, feedlots, packing plants, et cetera are located in rural areas and are large employers of much of the rural population. As with any agricultural commodity there is much volatility in the marketplace and this affects how these operations maintain profitability. Tools used for understanding these markets and presenting outlook into the future can be an essential part of efficiency for the beef industry.

The life cycle of most steer and heifer placements begins with the cow-calf sector. From birth to weaning, many calves are weaned at around 400 to 600 lbs. (Arthington, 2014). Calves at this weight are often put into a forage stocker program. Here the producer typically feeds mostly grass and forage, which aids in building frame and desired weight to enter the feedlot sector. The frame of the animal determines whether it is ready to enter the feedlot or continue as a stocker animal until it reaches the desired entrance weight for a feedlot. Stocker cattle continue on a diet of grass and forage feed until the up to 800 lbs. or so before entering the feedlot. Naturally, all cattle do not enter the feedlot at the same weight, but the typical weight is around 550 lbs. Therefore the stocker stage of cattle production can last upwards of 11 months (Nebraska, 2015).

The main focus of this thesis will be to explain and predict weekly slaughter production based on when feeders are placed in the feedlot on a monthly basis. A key to this analysis is weight gain of the feeder cattle. There are many factors that affect how animals gain weight, such as entering weight, frame, weather, desired weight, et cetera. When the animal enters the feedlot one of the main aspects that feedlot operators monitor is average daily gain (ADG) of steers and heifers. The average daily gain is the rate of weight gain per day over a specific period of time. This is an important element of cattle production, because it determines how fast the animal grows to slaughter weight. The (weight table 1.1) heavier animals have a higher intake of feed, increasing their average daily gain and reducing the amount of time they are in the feedlot. When an animal matures to desired slaughter weight can vary depending upon the frame of the animal as well as the current market conditions. The desired weight for slaughter also vary some depending upon the weight of the animal at the time of entering the feedlot (Table 1.1).

Table 2.1 Beef Production Stages Weight Table

| | |
|---|---|
| Weaned Weight | 300-650 lbs. |
| Target Feeder Placement Weight | 550-650 lbs. |
| Target Slaughter Weight | 1200-1400 lbs. |

(Arthington, 2014)

Importance:

Two markets of the supply chain are used to quantify beef production: monthly placement of steers and heifers into feedlots at different weights and weekly federally inspected slaughter numbers of fed cattle. For feedlot operations, feeders placed into the lots are an investment and their returns are realized when they are sold for slaughter. Analyzing the different placement weights and ways to determine aggregate beef production is important for understanding the live cattle market. The average daily gain and time on feed is also important for feedlot operations, as these influence the cost of gain for feeders. The time the feeders are in the feedlot has a definite impact on profitability. Production and market factors that affect the feedlot sector are unpredictable. With the limited supply issues that currently exist in the United States, better risk management strategies are an essential part of surviving and operating a viable operation.

For beef packers, it is crucial to comprehend inventories of fed cattle ready for slaughter to utilize plant capacities. Inventories indicate the number of cattle in the feedlot, however it is more difficult to determine the number that are actually ready for slaughter given seasonal peaks in placements, sex difference, weather, fluctuations, seasonal ADGs, and demand fluctuations. Achieving insight into factors that affect feeder cattle production will help mitigate fluctuation and risk while improving price bids for the feedlot and packing sectors.

Procedures and Overview:

In order to analyze cattle marketings, data from the United States Department of Agriculture (USDA) and Kansas State University's (KSU) feedlot program are utilized. These sources offer an overall look into aggregate numbers for cattle feeder placements, slaughter numbers, and final beef production through KSU's feedlot data. ADG can be fully examined and effects on the relationship between feeder cattle placements and slaughter numbers.

The USDA began gathering and publishing feeder cattle placement data in December of 1995. Placements utilized are classified into the following four different weight classes: <600 lbs., 600 to 699 lbs., 700 to 799 lbs. and 800 lbs. or more. USDA began collecting slaughter numbers by classes of animals beginning in January 1970, but accrual of average slaughter weights goes back to 1950. Data since 1995 is available for slaughter numbers, slaughter weight, and feeder placements. Placement data is on a monthly-basis while slaughter data is on a weekly-basis. Kansas State University first began publishing data pertaining to cattle feedlot production program. In January 1990, KSU reported ADG information that is used to help determine the length of time cattle are in a feedlot before reaching full slaughter weight.

Placement weights are the feeders' starting weights upon entrance to the feedlot and largely determine how long they will be fed to reach full finished weight for slaughter. The biological gain of the animal is due to elements affected by sex, weather, feed, et cetera. As for slaughter weight, the desired weight is typically between 1200 and 1400 lbs. Finishing weight also depends upon the various market conditions and the sex of the animal, naturally. Steer calves are typically slaughtered at heavier weights, however USDA does not specify the sex percentages in weekly slaughter data. Therefore we are unable to test the relationship between placement and slaughter separately for steers and heifers.

As mentioned earlier, the different classes of placement weights lead to different time periods by which the animal is fed in the feedlot. That is, lighter feeders will be on feed for longer times compared to heavier feeders. The same can be said for heavier-placed feeders, as they will likely have less time in the feedlot (i.e. 800 lbs. placed feeder only needs 400 to 500 lbs. for slaughter weight). One area that this study is looking to improve is presenting a more accurate representation of the average daily gain and determining a shorter time window by weight class that the animal reaches slaughter weight. The placement-weight data and average daily gain data are expected to improve fed cattle marketing projections. Cattle placed on feed at a particular weight class will typically be fed for a similar time period (depending on season) before slaughter so that their slaughter times match market projections. These are general concepts that will be quantified to provide an accurate representation of marketing projections detailed in this study.

Figure 1.1: Monthly Placement of Feeders for <600 lbs. and 700-799 lbs. Weight Classes (1000 head)

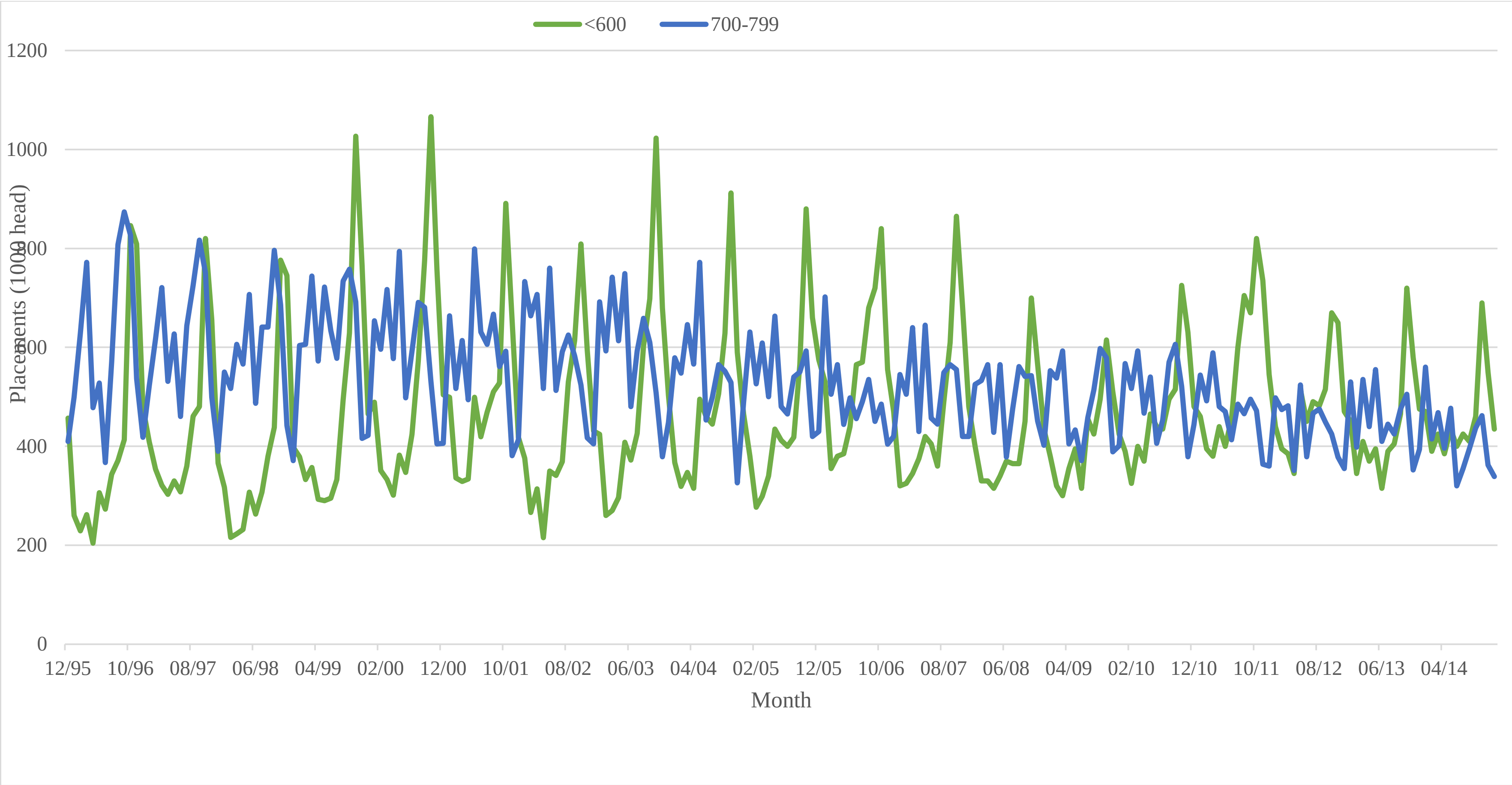


Figure 1.2:  Total Weekly Slaughter of Steers and Heifers (1000 head)

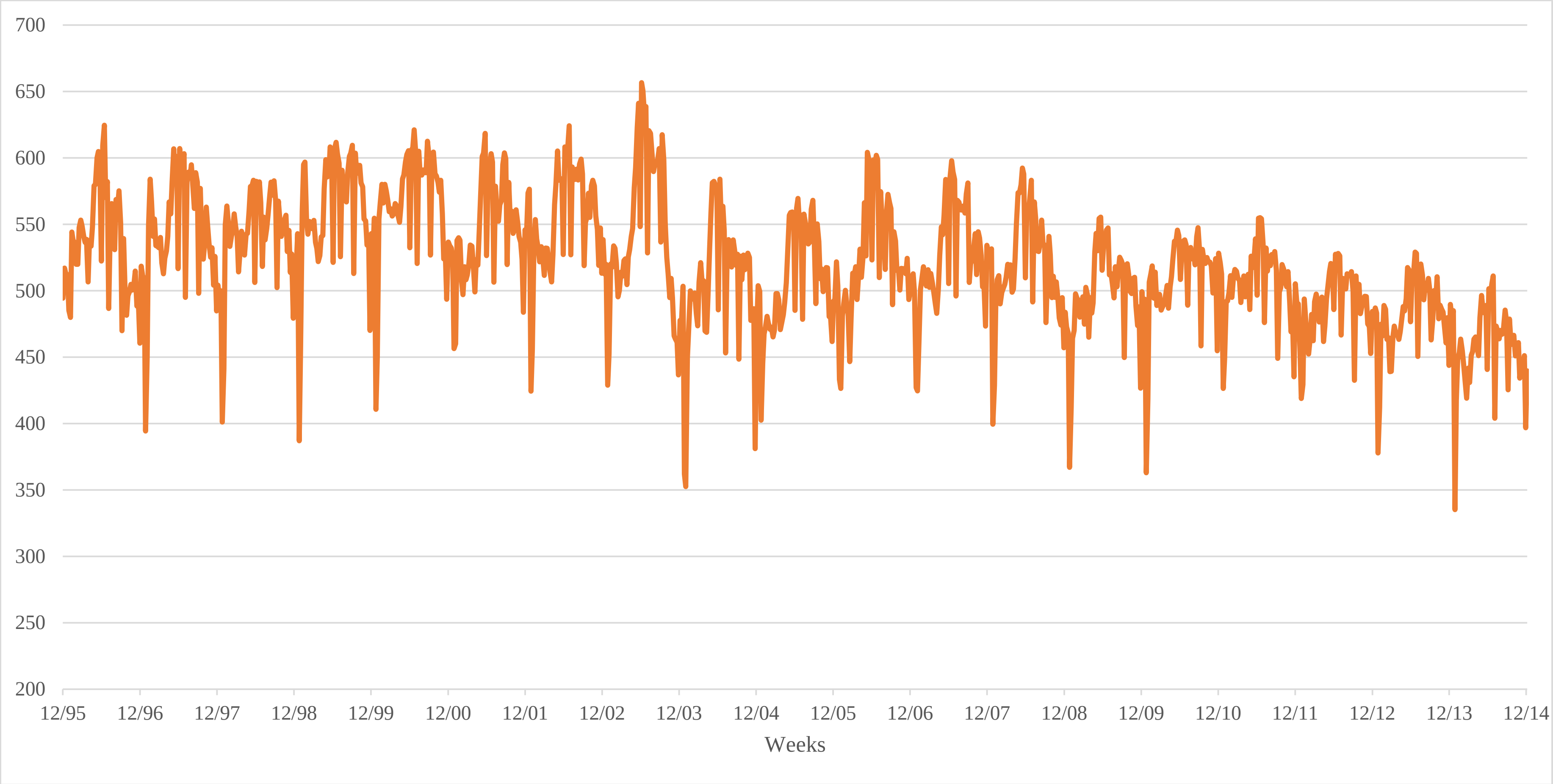
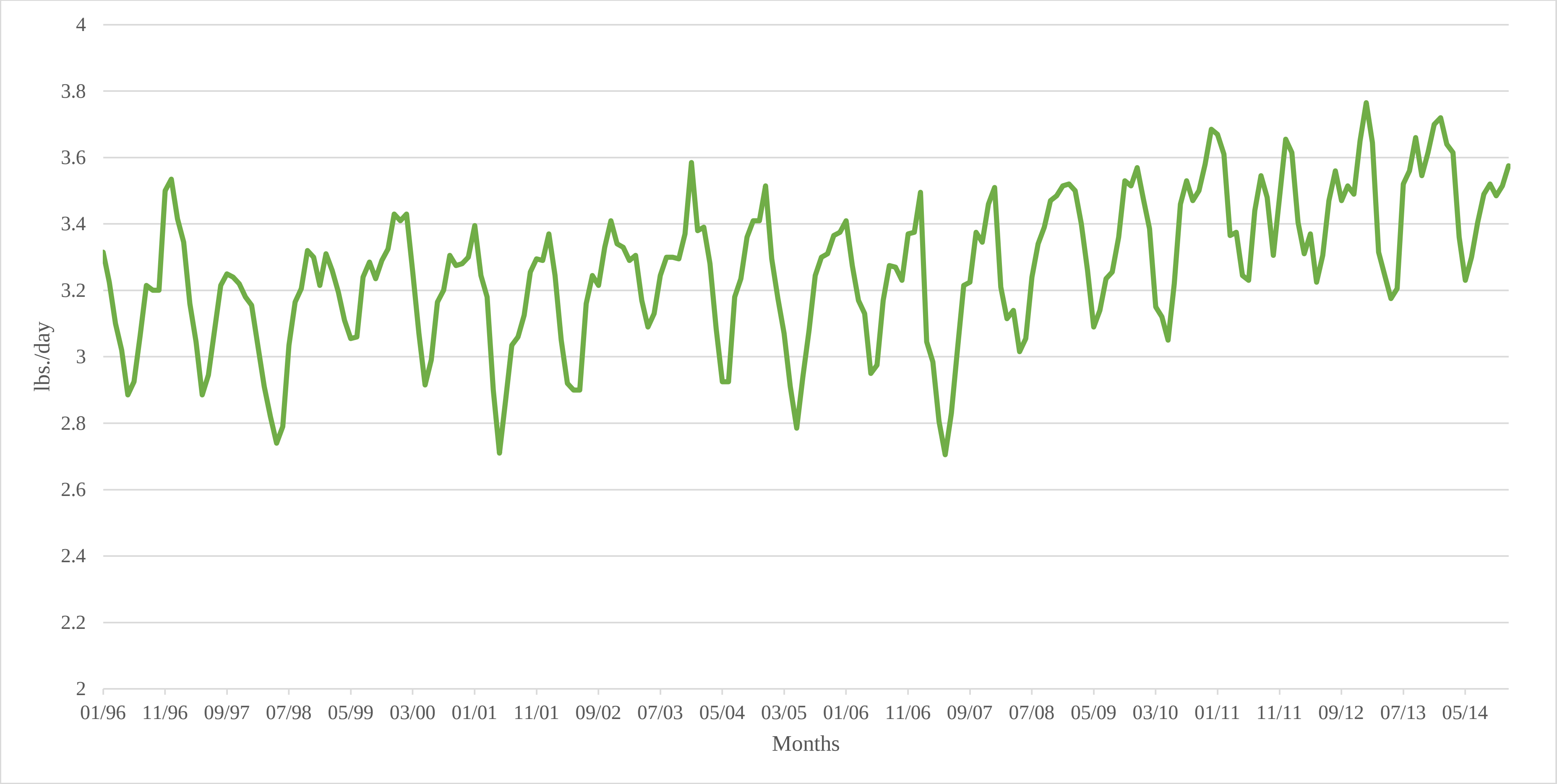


Figure 1.3: KSU Feedlot Program Average Daily Gain for Steers and Heifers; Jan. 1996- Dec. 2014



Overview of Placement, Slaughter, and Average Daily Gain:

Similar to packing plants, feedlot operators need a flow of cattle entering their feedlots on a regular and steady basis. When looking at placements across the various weight classes, it can be observed that there is a similar pattern of peaks and troughs of placements throughout time. Figure 1.1 demonstrates that the feeding and placement activities have been similar throughout the years. Monthly placements have a large range depending upon the month, the pattern changes regularly for each year depending upon the weight class. High placements typically occur towards the end of the year or fall, with a dip during the first quarter of the following year.

When examining weekly slaughter numbers (in thousands), the numbers do not present as much variance between the peaks and troughs, although they do fluctuate from year-to-year and within the year. The number of cattle slaughtered is fairly consistent until the end of the year where there is a steady drop in the numbers slaughtered due to the holiday season. There is a general downward trend in the number of cattle being slaughtered in overall slaughter numbers from December 1995 to December 2014, shown in Figure 1.2.

Average Daily Gain (ADG) is also a seasonal component of the cattle supply chain. Univariate statistics from KSU feedlot data show that average daily gains decrease during the times of more severe temperatures such as extreme cold or extreme heat. However as the majority of the animals are placed in the fall of the year, ADG increases as the weight of the feeder increases up to a certain level. The overall ADG between January of 2000 and January of 2014 indicates that the range of ADG is between <2 lbs. per day up to >4.5 lbs. per day. The seasonality aspects of feeder placement, slaughter, and average daily gain will be addressed in the Data and Seasonality sections of this thesis.

Contribution:

Feeder cattle marketing studies focus on the relationship between the monetary gains of feeding cattle and the costs of production. Much of the literature from the last decade also concentrates on the monetary gain of cattle feeding and new marketing techniques, specifically different pricing methods. Several studies place emphasis on increasing efficiency and profitability by better understanding the average daily gain of feeder cattle. Therefore, one of the contributions of this study is to quantify the relationship between monthly feeder cattle placements by class and the federally inspected weekly slaughter.

Scope and objectives:

This thesis is intended to yield more qualified information to fulfill the following objectives:

1. Formally estimate the relationships between feeder cattle placement, slaughter numbers, and average daily gain and beef production using an empirical model that quantifies the time period for feeder cattle to reach the desired slaughter weight for the packing sector.
2. Quantify and test for seasonal effects in the relationship between feeder cattle placements, slaughter numbers, and average daily gain.
3. Quantify market factors such as feed costs; quality premiums, and price premiums on grades of fed cattle, with weekly beef production.
4. Validate that the predicted weekly placements and weekly rate of gain are an accurate forecasting tools for predicting weekly slaughter numbers.

Literature Review:

Literature reviewed in this portion mostly pertains to feeder cattle production and placements in feedlots. The literature currently available on the subject is valuable in quantifying beef production with economic, seasonal, and biological factors. There are few studies that specifically look at using USDA monthly feeder placement numbers for forecasting and price determination. Studies focused on the quantifying economic, seasonal, and animal feeding factors are also reviewed. Livestock feeding tends to be a complex industry and there are many factors that play a role in the marketing and production. Therefore much of the literature pertains to tools used in quantifying these factors and understanding the forces that determine when cattle are marketed and why.

Norwood (2000) used monthly feeder cattle placements as a forecasting tool for price determination. The usefulness of monthly feeder cattle placements in forecasting cattle price and marketing techniques was studied. The research found that monthly placement data minimally improved market forecasts, but did not have any effect for price forecasting. The author used data from private consulting firms, Professional Cattle Consultants (PCC) and Cattle Fax, due to the limited number of years that USDA collected monthly feeder cattle placements. The data that PCC and Cattle Fax collected represents 20-25% of feedlot placements in the United States, whereas the USDA data captures a much larger percentage of placements and should be a more accurate source of feeder cattle placements (Norwood, 2000).

The studies on cattle production in a feedlot are necessary for estimating beef production flows. Factors that effect beef production flows can include the animals' genetics, diet, average daily gain, weather conditions, and other factors that will influence when feeder cattle are marketed for slaughter or placed into the feedlot. Thus, the research that looks into cost of gain and daily gain are essential for accurate forecasting and marketing decisions.

Rahman (2006) studied feedlot decision-making based upon existing cattle feeding contracts under fed-cattle pricing methods. One of the challenges that many feedlot operators and cattle owners face is fed-cattle marketing. The literature on feeder cattle marketing looks into alternative methods to contract feeder cattle sold for slaughter. In "*Optimal Incentive Structure in Cattle Feeding Contracts Under Alternative Fed Cattle Pricing Methods"* (Rahman 2006) the author analyzes the incentive provisions in existing cattle feeding contracts under fed cattle pricing methods. The author is simulating various scenarios on which feedlot operators and cattle owners form contracts based on two different contract criteria, which are rate of gain contracts and yardage fee contracts. The main findings from the simulation are that yardage fee contracts are optimal for the cattle owner of the high-performance graded fed cattle priced on the grid contract. On the other hand, the cost of gain contract is optimal when the cattle are to be marketed according to live-dressed weight. These two ways of marketing are much debated in the fed-cattle industry (Rahman 2006).

In *Evolving Producer-Packer-Customer Linkages in the Beef and Pork Industries*, Schroeder (2001) analyzes the linkages between the livestock industry and consumer demand, quantify the relationship, and present an overall future on the market. The beef industry as a whole is seeing decreased consumer demand in comparison to substitute protein sources: pork and poultry. The reason for this decrease is changes in quantity demanded of beef that is partially due to competitive pricing of pork and poultry owed at least partially to their vertically integrated production processes (Schroeder, 2001). Based on LMIC.info, this continued trend of quantity demanded is less for the beef industry. There are other more complex reasons for this decrease in demand such as: health reasons, inconsistency in beef pricing vs. pork and poultry, changes in diets, etc. Three-fourths of the feeder cattle are sold through livestock auctions, with little information from grades and prices at the slaughterhouse being paired back to ranches. There is much more room allowed for vertical integration of the beef industry, thus driving prices to be more competitive with pork and poultry. To increase profits, the industry has developed production-marketing practices such as grid pricing, formula pricing, short-long term marketing agreements, and strategic alliances (Schroeder, 2001).

Schroeder (2001) specifically looks at two types of contracts for feedlots and how incentives affect the performance of the livestock and outcome marketing techniques. The traditional way that fed cattle have been sold is by live weight or average dressed weight. Other than market price, average weights of the animal are the sole factor that determines value. Therefore, this leaves possibility for error in quality differences for the buyer. Grid pricing is the alternative, which is selling fed cattle at value-based marketing on an individual animal basis. Quality and dressing percentage are driving factors for determining an individual animal's value compared to historically selling on just weight. For price bids, the choice-select price spread is critical for marketing the quality of animal and feeding costs are also a heavy determinant of profitability.

For the simulation and analysis, Schroeder et. al. examines incentives to use the two types of contracts. The cost of gain contract is described as the feedlot operator provides all inputs except the cattle and is reimbursed on the basis of a negotiated price per lbs. gain on the livestock weight. A yardage fee contract is payment to the feedlot operator based on a fixed charge per day per animal plus reimbursement for the feed consumed. The simulation is based upon a feedlot in southwest Iowa during the most common season for fed cattle entering the feedlot, which is the fall of the year, and leaving during the summer months. The biological growth of the cattle was simulated using a bio-physical growth model, common in the animal science literature. The stochastic costs and returns of the feeder cattle operator and feeder cattle owner were calculated in a Monte Carlo fashion, using historically weekly average prices and a feedlot budget.

The main findings of this study indicate that for the cattle owner's point of view, the yardage fee (zero incentive for the operator) contract is optimal when the cattle are priced on the grid system. The cost of gain contract (high incentive for yield) is optimal when the cattle are to be marketed according to the average live weight or dressed weights.

To determine factors that influence when cattle feeding operators to market their cattle and what factors are the most influential, much of the literature describes the variability with the seasonal effects of placements and market factors. In *Identifying Economic Risk in Cattle Feeding,* Mark, Schroeder, and Jones (2000), look at closeout data from two Kansas feedlots to determine how cattle, prices, feed costs, and animal performance impact the variability of cattle feeding profits. The relative impacts of these factors are studied across sex, placement weight, and placement month using standard beta coefficients. They find that feeder cattle prices have a greater impact on profit variability for spring and fall placements; the effect of animal performance on variability of cattle feeding profits is greater for fall placements. Their results suggest that fed cattle and feeder cattle prices should be emphasized in managing the overall risk in cattle feeding because of the large contribution they play in profit variability (Mark, 2000)

The data used is from two commercial feedlots in western Kansas. The feedlots provided closeout data for 14,183 pens of cattle finished from January 1980 through March of 1997. The data included placement weight, finished weight, days on feed, average daily gain, feeding cost, purchase price and selling price. The data was also augmented with corn prices, interest rates, feeder cattle prices, and fed cattle prices. This research provides an overall look into the factors that influence the risk of cattle feeding for a feed yard. Most of the literature that looks at the risk of cattle feeding operations has the same parameters that are influencing cattle feeding profitability.

Profit per head was calculated from subtracting the cost of the feeder and the total feeding costs from gross returns. Total feeding cost will vary with corn prices, interest rates, and animal performance. Profits per head are a function of sale price, purchase price, corn price, and animal performance. Average daily gain and feed conversion were used to determine animal performance. The objective of the study is to determine the relative impacts of the various factors on cattle feeding profits. Ordinary least squares regression coefficients were used and found to be difficult to compare. Therefore normalized the independent variables to have a mean of zero and a variance of one. Regressing the normalized independent variables on the normalized dependent variable yields the standardized beta coefficients used for comparison.

The results demonstrated that all coefficients were statistically significant, as expected fed cattle prices and ADG are positivity related to feeding profits, whereas the remaining variables negatively affect profitability. The standardized beta provides meaningful comparisons on the impact of the variability of indented variables on profit per head, however they do not account for correlation or covariance between related variables. It was found that feeder cattle prices have a similar impact across placement weights with the same sex.  Feeder cattle prices increase as placement weight increases, which reflected increased importance of feeder cattle costs when placing heavier cattle.  From the regression results, fed cattle price has the largest impact on profit per head followed by feeder cattle price, corn price, feed conversion, interest rates and average daily gain. The impact of the explanatory variables varied by seasonal effects, corn price had the most impact on variability during the month of October which can be explained by grain harvest during this month and placements beginning to ramp up into feedlots.

Fed cattle prices and feeder cattle prices have greater impact on cattle feeding profitability than corn prices, interest rates, and animal performance. This suggests that risk management efforts should be focused on supervising price risk in those markets to reduce riskiness associated with cattle feeding. These other explanatory variables explain economically important amounts of profit variability. In general as placement weight increases, feeder cattle prices impact profitability more, whereas corn prices, interest rates, and animal performance influence profitability less. Feeder cattle price variability has a greater impact on spring and fall placements and corn price seasonally has an impact on placements during the fall of the year.  Finally ADG affects profits most for late fall placements. Seasonal prices, placements, and animal performance play a large role in determining profitability for beef producers. This research contributes to the understanding of the impacts that effect cattle feeding profitability and factors that most influence the timing of marketing fed cattle (Mark, 2000).

The review of past literature on ADG, placements, and seasonal affects are necessary to determine future market strategies and overall beef production. The purpose of this literature study is to examine past research that can lead to further understanding of the benefit of estimating the relationship between feeder placements and federally inspected slaughter numbers.

# CHAPTER 2: DATA AND SEASONALITY

The USDA placement, slaughter, KSU average daily gain, price premium, and feed cost data were all gathered from the Livestock Marketing Information Center (LMIC). The LMIC is an organization that is focused on providing economic and market analysis for the livestock industry. It is composed of partnerships between land-grant universities, USDA-NASS partners, private industry partners, and LMIC staff all contributing expertise and funding to this database and associated economic analysis. The time series for this analysis extends from December 1995 to December of 2014.

The origination of the data for the feeder cattle placements is concentrated mostly in the cattle feeding regions of the United States. Placement data are divided into five categories consisting of the four leading states Colorado, Nebraska, Kansas, Texas, and an aggregate of all other states. (Table 2.1). The reports of placement data come in 1000 heads from 1000+ capacity feedlots collected by USDA.

Table 2.1: Average monthly feedlot placements (from December 1995-December 2014 in 1000s of heads)

| | <600 lbs. | 600-699 lbs. | 700-799 lbs. | >800 lbs. |
|---|---|---|---|---|
| **Colorado** | 32 | 39 | 58 | 60 |
| **Kansas** | 79 | 107 | 143 | 110 |
| **Nebraska** | 69 | 86 | 108 | 143 |
| **Texas** | 154 | 136 | 133 | 67 |
| **Other States** | 130 | 76 | 91 | 126 |

(Center, 2015)

Table 2.1 shows that the four states listed are the main feedlot states in comparison to all other states that have 1000+ head capacity feedlots and feeder cattle. The average monthly placements give an indication of the diversity and variation that occurs in cow-calf production systems with differences in weight placement, plus seasonal and regional differences. Looking at Texas, the majority of the feeders are placed into the feedlot with <600 lbs. weight. In the more northern states such as Nebraska, the exact opposite placement trend is clear with the largest number of cattle entering the feedlot at the heavy end or >800 lbs.

The USDA has also been collecting weekly federally inspected data of all cattle slaughtered in the United States. Total federally inspected slaughter numbers are generally comprised of ~80% steers and heifers with the other 20% consisting of cows and bulls. One of the main aspects of this research is using feedlot placements of steers and heifers by weight class to estimate future fed cattle slaughter numbers (Center, 2015).

Data used for determining average daily gain comes from Kansas State University's (KSU) monthly performance and feed cost closeouts. KSU publishes a monthly publication *Focus on the Feedlots*, initiated in 1990 to provide basic feedlot performance data for steers and heifers, and feed ingredient prices. Each month, closeout data from various Kansas feedlots are summarized to provide average values for days on feed, average daily gain, initial weight, live weight before slaughter, dry matter feed conversion, cost of gain, and death loss, as well as corn and alfalfa hay prices. This information is useful for determining the rate of ADG's for this study. This is needed for determining the amount of time feeder cattle are in the feedlot. Data from KSU also provides a range of minimum and maximum ranges for rate of gain, initial weight and end weight, as well as various feeding cost and percentage death loss information. LMIC collects and compiles this data so access and utilization was simplified in aiding the determined time feeders are in the feedlot (University, 2013).

Market factors and quality premiums play a role in determining optimal time that fed cattle are sent to the packing sector. Feed costs are one of the most important areas that need to be addressed in beef production and profitability. There are many different rations and feeding programs that feedlots follow but the vast majority of feeder cattle diet consists of corn. Therefore, the spot corn price in Kansas will be used to proxy the cost of gain.

The other relationship that will have an effect on when cattle are marketed is quality of beef cutouts. USDA grades beef cuts based upon quality. The three categories that are from most desirable to least desirable are: USDA Prime, USDA Choice, and USDA Select. The desirability of beef comes from the various palatability factors that affect tenderness, juiciness, and flavor. These factors include carcass maturity, firmness, texture, and color lean, and the amount and distribution of marbling within the lean. Beef carcass quality grading is based on the degree of marbling and degree of maturity (Dan Hale, 2013). The price premium is used in this study to examine this quality relationship is the price spread between choice and select cuts. With more desirability in the prime and choice cuts, the price premium increases for these cuts. When determining slaughter weight, a higher percentage of animals will grade choice when their weights are heavier versus if an animal is lighter when it is slaughtered it may grade select, thus the price premium for this cut will be applied. The choice-select price spread prices can be found on the members section of the LMIC.info website as well. For the model estimation, data is used starting in Dec. 1995 to Dec. 2012, while the years 2013 and 2014 are used for forecasting and validation to check out of sample model accuracy.

In the forecasting analysis, total beef production is desired. In order to determine future beef production, a proxy for total production is created. LMIC releases weekly average dressed weights for steers and heifers and the weekly slaughter numbers to give a proxy for total production multiplies these weights. Average dressing weight is utilized because it establishes the weight upon which payment is calculated for animals sold on a live weight basis. For example, an animal may weigh 1300 lbs. when sold live, but after the removal of the hide, feed, gut, etc. the remaining weight represents the meat and skeletal portion of the animal. This dressed weight, as well as grading quality, are the factors that determine the value per head of slaughtered animals. Utilizing average dressed weights provide a more thorough look into the actual value of the animal by weight. Average dressed percentage of steers and heifers vary, heifers usually have a 1.5- to 2.0-percentage point lower dressing percentage than steers at a similar fat level. The difference in dressing percentage between steers and heifers narrows as heifers become fatter than steers. Since heifers mature earlier, they are usually marketed 100 to 150 lbs. lighter than steers. LMIC publishes steer and heifer average dressed weights and slaughter numbers, the average dressed weight of each sex with be multiplied by the slaughter number of each sex then aggregated to give total production (Development, 2015).

Figure 2.1: Average Dressed Weights for Steers and Heifers; Jan 1996- Dec. 2014

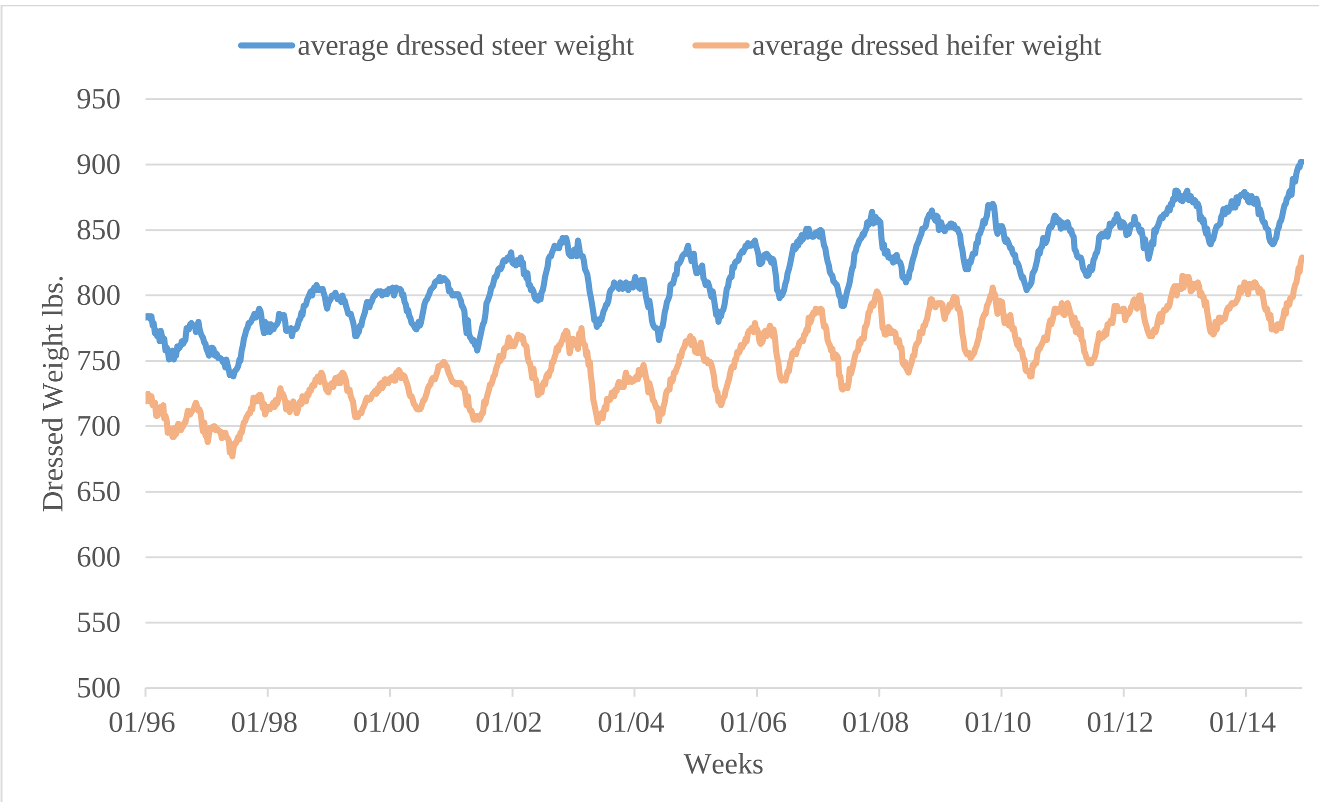
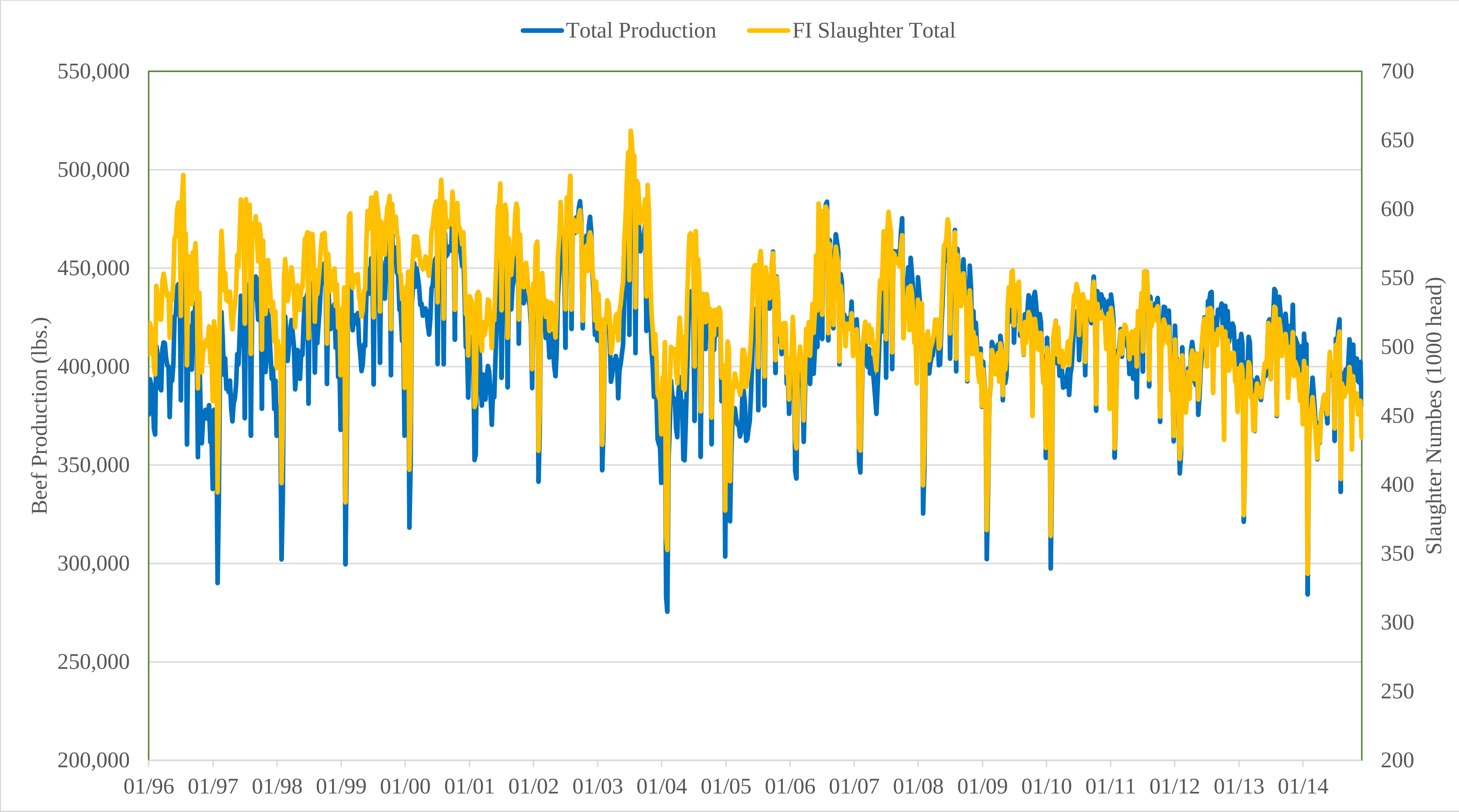


Figure 2.2: Total Production using Aggregate Steer and Heifer Slaughter Numbers and Dressed Weights vs. Total Slaughter Numbers; Jan. 1996- Dec. 2014

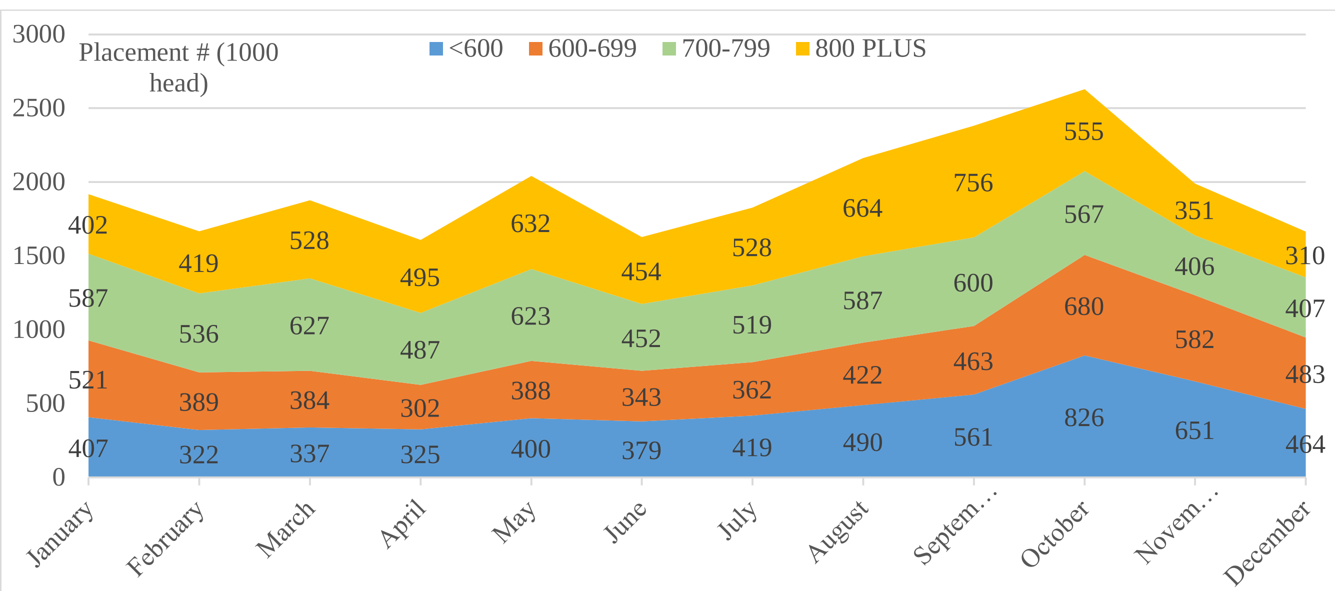


Seasonality:

Seasonality is a cyclical pattern, which repeats at regular intervals within an annual time period. The effects of seasonal noise on regression estimates are considered a form of systematic error in the analysis. Thus, seasonality needs to be accounted for to reflect accurate economic changes in the variables. Seasonality is often found in most time series analysis, and in this project seasonality is very evident in the feeder cattle placements, slaughter data, and rate of gain. Along with seasonal effects in this time series there are general trends that are increasing or decreasing in the data. A model for estimating seasonality will be utilized for this analysis.

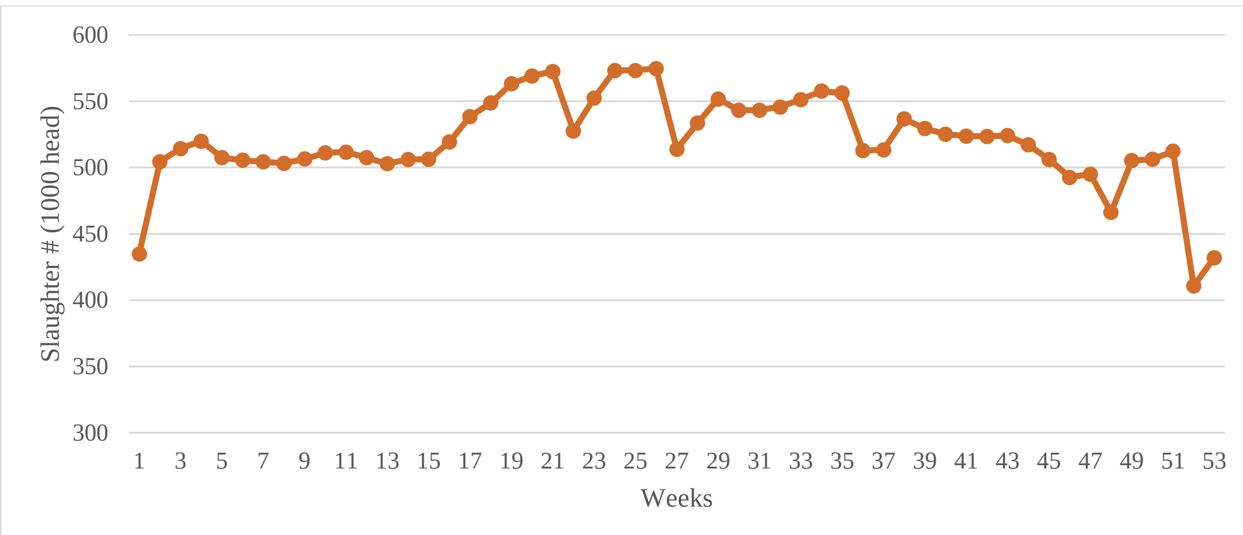
For feeder cattle placements, numbers of cattle entering the feedlot increase and decrease around the same time annually. The annual recurrence trend can be examined in Figure 2.3, which displays average monthly placement values for each weight class over a 19-horizon (from Dec. 1995-Dec. 2014). For each class, placements climb up a little in March and May, and fall back down to a low level in April and June. Then they start increasing in July and peak in the fall of the year. The heavier feeders peak during September for the heavier two classes, while the lighter weight classes seem to reach their height later in October. Placements then drop sharply towards the end of the year.

Figure 2.3 Monthly-Annual Average of Feedlot Placements; Dec. 1995-Dec.2014



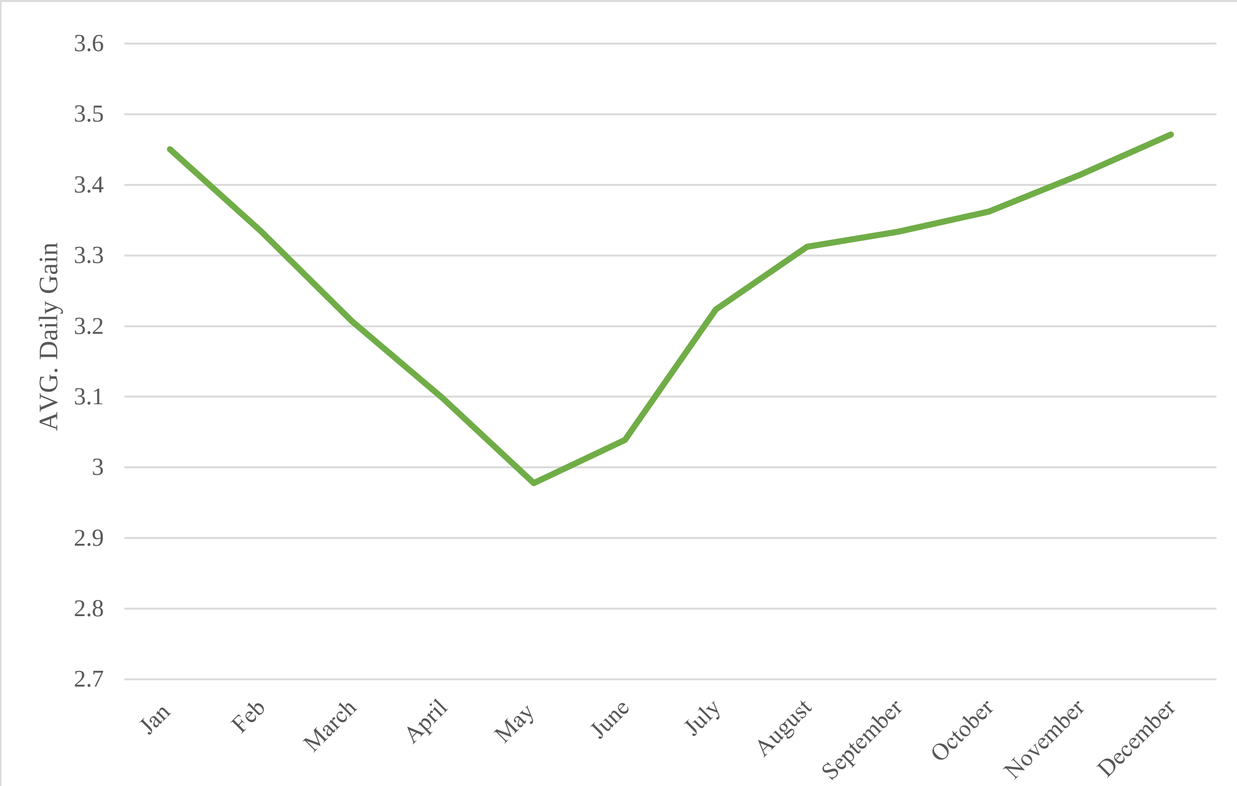
In comparison with dramatic seasonal changes in placements in figure 2.3, weekly slaughter numbers for the same period Figure 2. show that slaughter numbers are relatively smoothly distributed over the year, with the exceptions of a few drops in weeks 22, 27, 36, 48 and the beginning and end of the year. These decreases in slaughter are due to national holidays such as Labor Day, Fourth of July, Thanksgiving, Christmas, and New Years. These are days when the packing plants are closed and thus have no slaughter. Seasonality also occurs when looking at the rate of gain data from KSU.

Figure 2.4: Average Weekly Slaughter Numbers; Dec. 1995-Dec 2014




The KSU average rate of daily gain spans the horizon of January 2000 through August of 2014 Figure 2.5. The average daily gain shows a cyclical pattern for when cattle gain most depending upon which season and when they are placed. For the time horizon examined the ADG decrease after the first of the year due to colder weather for the time on feed. ADGs start to increase in April due to warmer spring weather. With the majority of placements occurring during the fall of the year, the gradual increase in average daily gain is logical due to as the animal increasing in size and the amount of weight they will gain. Modeling for the seasonality of these variables is a major consideration in this analysis.

Figure 2.5 Monthly KSU Average Daily Gain; Dec. 1996- Dec. 2014




<u>Factors Influencing Seasonality:</u>

There are several factors that cause seasonality in feeder cattle production. Climate of cow-calf operations, diverse genetics, and seasonal demands have an effect on cattle (Mark, 2000) In "*Identifying Economic Risk in Cattle Feeding*" Mark, Schroeder, and Jones (2000) look at environmental and diverse range conditions targeted for feedlots in Kansas and the factors that affect profitability there. Challenges that feedlot operators might face include: seasonal components of prices, weather, placement weight, etc. and these factors will have an effect on the profitability of cattle feeding, rate of gain, and marketing techniques. The authors illustrate how weather and climate affect cattle feeding, that optimal cattle feeding performance generally occurs with temperatures between 40 and 60 degrees Fahrenheit. When temperatures are colder, the energy spent on maintaining body temperature increases resulting in less gaining of weight, while when it is very warm feed consumption declines. Humidity is an element that influences the rate of gain. High humidity levels can increase heat stress on cattle resulting in decreased feeding consumption and higher chances for death loss. Weather gives an obvious indication where rate of gain and placement will be affected depending upon the location of the feedlot and how feedlots are operated.

Other than weather and climatic changes, economic factors play a role on seasonality and profitability of feedlots. During the fall months of the year, grain harvest is occurring in much of the Midwest, which typically result in lower corn prices, allowing for cattle feeders to take source lower feed costs. With feed supplies high it is common to see more placement into the feedlot in the fall of the year. When feed supplies are tightened, more calves are backgrounded as stockers. The increased placement of feeders in the fall also impacts beef production. To maintain profitability in cattle feeding, feedlot operators attempt to maintain a steady flow of cattle into the feedlot. For the two lightweight classes, since they are mostly recently weaned, the natural environment will have more of an effect on their production versus the heavy weight groups. When the animal is placed at a heavier weight the amount of time that is spent in the feedlot declines versus a lighter weight placed animal, which will extend the amount of time, spend in the feedlot. Quantifying placements and rate of gain is a challenge for this study, due to the high amounts of seasonality as well as the large amount of variation in animal genetics, environmental, and markets that have an effect on feeder cattle production.

<u>Model used for estimating seasonality:</u>

Much of the data demonstrates strong seasonal patterns. In order to eliminate seasonal systematic events that are recurring such as weather, biological lags, and seasonal markets, seasonality is estimated. These seasonal adjustments allow for easier observation and analysis of the non-seasonal factors within the data. The method that was used for adjusting for seasonality was previous worked on in this project and will be used further with more expansive data. The “static” framework to estimate seasonality in the conditional means, variances, and covariance’s are used. Aradhyula and Tronstad (2006) argue for the use of a “static” framework when random shocks occur in finite memory. These events are purged from known estimated seasonality variables so that seasonal effects do not have an infinite memory, as in a dynamic framework. The seasonality of feedlot placements and average daily gain from KSU will be seasonally adjusted and estimated. Federally inspected slaughter data will not be adjusted for seasonality due to the relativity steady slaughter and consumption with the exception of holidays. These holidays will be quantified in the model using dummy variables (Aradhyula Sateesh, September 2006). The equation used for estimating seasonality is:

(2.1) $$(1 - L)\left(Q_t - S_t^q\right) = \varepsilon_t$$

(2.2) Where, $$S_t^q = a_1 m_t^1 + a_2 m_t^2 + a_3 m_t^3 + \cdots + a_q m_t^q,$$

$$\sum_{j=1}^{q} a_j = 0, \quad and \quad \sum_{j=2}^{q} j a_j = 0$$

In equation (2.1), $Q_t$ is the quantity of feedlot placements in month *t*, $L$ is the lag operator, $S_t^q$ is seasonality of feedlot placements. The term $m_t$ is the month of the year dived by 12, which gives a time index that cycles between 0 and 1, $a_j$ are coefficients, and $q$ being the order of the polynomial which needs to be determined for each weight category of feedlot placements. Seasonal coefficients must satisfy the condition that seasonality is equal at the beginning and end of the year, i.e.,

(2.2a) $$S_t^q(0) = S_t^q(1) \ or \ \textstyle\sum_{j=1}^{q} a_j = 0,$$

And that seasonality is smooth across years, i.e.,

(2.2b)

$$S_t^q(0) = S_t^q(1) \ or \ \sum_{j=2}^{q} j a_j = 0.$$

The seasonality component estimated in equation (2.1) and the monthly lagged feedlot placements, will then be used to generate weekly feedlot placements for the four weight groups respectively. The next equations are further details of (2.1) that are used further in the analysis.

(2.3) $$Q_t = Q_{t-1} + (S_t - S_{t-1}) + \varepsilon_t$$

Substituting equation (2.2) into (2.3) yields,

(2.4) $$Q_t = Q_{t-1} + a_1(m_1 - m_{1-t}) + a_2(m_{2-}m_{t-1})^2 + a_3(m_3 - m_{t-1})^3 + \cdots + a_q(m_t - m_{t-1})^q + \mathcal{E}_t,$$

Where,

$$\sum_{j=1}^{q} a_j = 0, \quad and \quad \sum_{j=2}^{q} j a_j = 0$$

From equation (2.4), a model linear in the coefficients between quantity of monthly placement *Q* and the time indicator *m*, for a polynomial order *q* of coefficients *a* will be estimated.

Model fitting criteria and seasonally adjusted pattern:

To determine lag length and polynomial order, the Schwarz criterion was utilized. The Schwarz criterion is also named the Bayesian Information Criteria (BIC). When performing the model fitting criteria, the lowest BIC value is desired. BIC is a method that has been found to be unbiased for selected orders of lags and polynomials. The BIC is defined as:

(2.5) $$BIC = n * \ln\left(\frac{SSE}{n}\right) + k * \ln(n),$$

The value *n* is the number of observations for the model, *k* is the number of coefficients to be estimated, and *SSE* is the sum of square errors. The BIC is an increasing function of both *SSE* and *k*. Therefore when the number of coefficients is the same, a lower BIC value will be affiliated with a lower SSE, which results in the better estimate of the model. Table (2.1) gives the Schwarz criteria values. Based on these values the appropriate polynomial order for each weight class is decided and the "*a*" coefficients are determined.

Table 2.2: Schwarz Criteria Values used to determine Unbiased Polynomial Order:

| Order | < 600 lbs. | 600-699 lbs. | 700-799 lbs. | > 800 lbs. |
|---|---|---|---|---|
| 5 | 1943.72 | 1904.61 | 1991.64 | 2010.07 |
| 6 | 1931.06 | 1903.17 | 1960.36 | 1958.03 |
| 7 | 1897.29 | 1876.83 | 1943.85 | 1935.17 |
| 8 | 1862.25 | 1836.8 | 1949.14 | 1918.21 |
| 9 | 1828.51 | 1809.32 | 1953.56 | 1895.77 |
| 10 | 1828.02 | 1814.5 | 1957.36 | 1898.97 |
| 11 | 1795.07 | 1736.6 | 1886.71 | 1868.9 |
| 12 | 1840.22 | 1815.66 | 1933.98 | 1878.96 |

Table 2.3: Table Containing Estimated "a" coefficients

| Parameters | < 600 lbs. Estimates | Standard Error | 600-699 lbs. Estimates | Standard Error |
|---|---|---|---|---|
| a1 | 54905 | 1172 | 71884 | 1015 |
| a2 | -1758430 | 27441 | -2261453 | 23777 |
| a3 | 22204383 | 243273 | 28639579 | 210789 |
| a4 | -151600000 | 1074055 | -197100000 | 930640 |
| a5 | 630570000 | 2591355 | 826900000 | 2245339 |
| a6 | -1690000000 | 3398766 | -2234000000 | 2944940 |
| a7 | 2980200000 | 2047752 | 3968800000 | 1774322 |
| a8 | -3441000000 | - | -4611000000 | - |
| a9 | 2504200000 | 469457 | 3371800000 | 406772 |
| a10 | -1042000000 | - | -1408000000 | - |
| a11 | 188830000 | 86175 | 255900000 | 74668 |
| **Parameters** | **700-799 lbs. Estimates** | **Standard Error** | **> 800 lbs. Estimates** | **Standard Error** |
| a1 | 92295 | 1467 | 49210 | 1404 |
| a2 | -2885700 | 34351 | -1581509 | 32884 |
| a3 | 37028367 | 304534 | 20857458 | 291528 |
| a4 | -258000000 | 1344521 | -148900000 | 1287102 |
| a5 | 1094600000 | 3243905 | 644890000 | 3105370 |
| a6 | -2985000000 | 4254637 | -1790000000 | 4072939 |
| a7 | 5345700000 | 2563414 | 3247900000 | 2453940 |
| a8 | -6249000000 | - | -3833000000 | - |
| a9 | 4590200000 | 587675 | 2832900000 | 562578 |
| a10 | -1922000000 | - | -1190000000 | - |
| a11 | 349890000 | 107875 | 216770000 | 103268 |

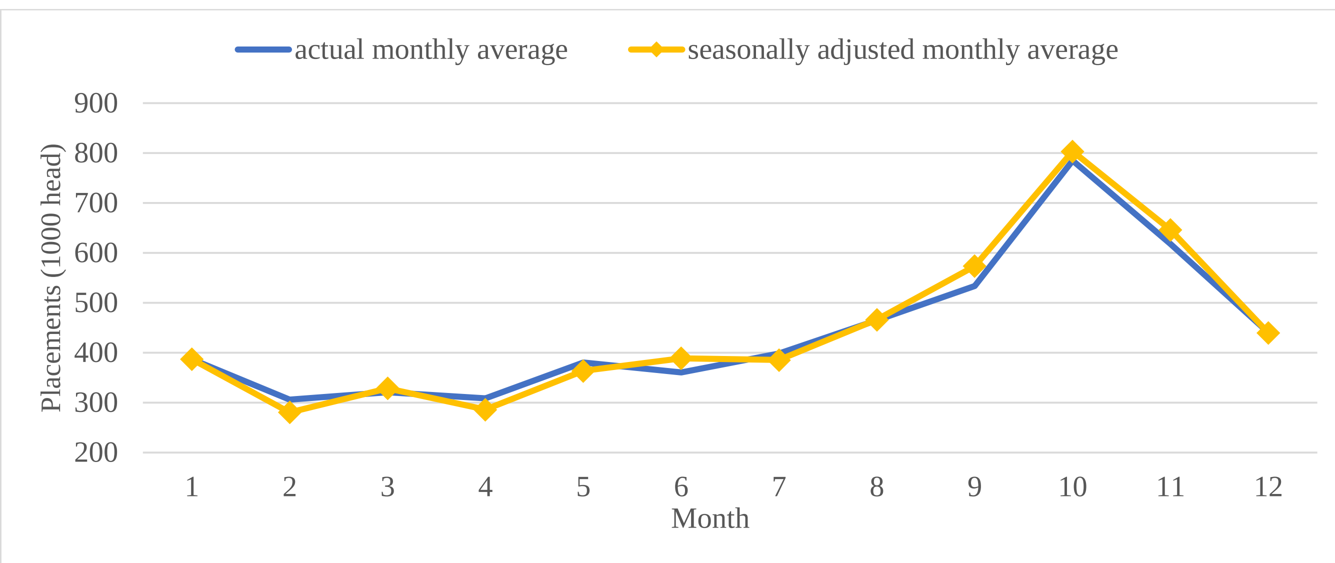
(Estimates significant at the 1% level)

For the weight class of <600 lbs., 600-699 lbs., 700-799 lbs., and the >800 lbs. weight groups, the polynomial order is 11. After the seasonality coefficients are determined for each weight class, the seasonality terms are placed back into equation (2.1). Then, the seasonal adjusted monthly placements $\widehat{Q_t}$ can be derived as:

(2.6) $$\hat{Q}_t = Q_{t-1} + (S_t - S_{t-1}),$$

The purpose behind using the seasonally adjusted placements provides a smooth pattern for transforming monthly feeder placements to weekly feeder placements. Using a polynomial function provides a smooth and continuous seasonality pattern throughout the time series analysis. The seasonally adjusted versus actual monthly placements can be observed in Figure 2.5 for the <600 lbs. weight class, the other weight classes can be found in the Appendix.

Figure 2.4: Seasonally Estimated Monthly Average Placements vs. Actual Monthly Average Placement for <600 lbs. Feeders



Transforming Monthly Placement data to Weekly Placement Data:

As explained earlier in this study, USDA publishes a monthly report with the feeder cattle placement numbers entering the feedlot based upon weight class. USDA also publishes a weekly federally inspected slaughter numbers report explaining the number of animals that were slaughtered for the week. Thus, either the monthly placements need to be converted to weekly placements or the weekly slaughter needs to be aggregated to monthly slaughter. For this analysis, monthly data will be converted to weekly data. Weekly data has the potential to give a more granular look into the relationship between feeder cattle placement and slaughter and is one of the main contributions of this analysis. The motivation for the transformation is that it can provide weekly information to feedlot operators and packing plants with weekly placement data which than can be compared to future weekly slaughter data.

The three approaches used to convert the monthly placements to weekly are as followed. The first approach is transforming the data by keeping a constant value of placements for all the weeks in the month. The monthly placements are divided by the number of days in the monthly multiplied by seven days in the week. This gives a constant weekly placement value for a month, depending upon the number of days in the month and is abbreviated as “WP”.

Econometric software packages, such as SAS, can transform monthly data to weekly data using PROC EXPAND procedures. In SAS the PROC EXPAND procedure is used to aggregate time series data or de-aggregate time series data-based upon the desired time series data. SAS software is equipped with past calendar dates for allocating the proper data to the desired de-aggregate time series. Therefore for my analysis, SAS is able to perform the monthly to weekly placements by allocating to the appropriate days and weeks of the month. This transformation method provides a more continuous and smooth seasonally-adjusted pattern of the transformed weekly data. One benefit to this transformation method is that it provides minimal time to transform the data. In the following method, the time it takes to perform the seasonal adjustment is more tedious and requires updating the seasonality model components when updating the time series versus the PROC EXPAND procedure, which automatically adjusted for seasonality and is labeled as “SP” (SAS, 2010).

Although seasonality is estimated using monthly data, the amount for a week or day can be determined to allocate actual monthly placement to their estimated weekly seasonal pattern, seasonality constraints were imposed using the Solver function in Excel to transform the data from monthly to weekly frequency and ensure that both absolute and percentage adjustments were appropriately allocated. That is actual placements for month “$t$” what would be expected for levels that existed the prior month; weeks with a higher estimated seasonality in month “$t$” receive a larger allocation of the placement numbers. Consideration needs to be made for the number of weeks and days in each week for a month. For example if there are 31 days in a month, 2 days in the first week, 1 day in the last week of the month and 4 full weeks in-between, therefore this month has a total of 6 weeks represented. Therefore using the appropriate Solver function constrains, the number of days are appropriately allocated by the placements based upon the days in the week assigned. This allows for giving the proper amount of monthly placements for the number of weeks without overlapping.

The equations constrained to fulfill the Solver function are as followed:

(2.6) $$S_{wt}^{q} = a_1 m_{wt}^{1} + a_2 m_{wt}^{2} + a_3 m_{wt}^{3} + \cdots + a_q m_{wt}^{q},$$

“$q$” and “$a$” are the polynomial order and seasonality coefficients which are obtained from equation 2.4. “$m_{wt}$” is a time indicator, which equals days of the year/365 or 366 depending upon the leap year. “ $S_{wt}^{q}$ " is the weekly seasonality component, which when defined the weekly placement shown in week 1 to week 6 in a month will be defined as:

(2.7) $$Placement_{wt} = Percentage_{mt} * \{\left(days\ in\ the\ \frac{week_t}{7}\right) * [\left(actual\ placement_{mt} + \left(S_{wt}^{q} - S_{w(t-1)}^{q}\right)\right]\}$$

Lastly, the target cell is set up as:

(2.8)

$$\sum_{wk1}^{wk6} Placement_{wt} - \hat{Q}_{mt} = 0$$

"$\hat{Q}_{mt}$" is the seasonally adjusted monthly placement obtained from equation (2.5). The subscript *mt* means month represented by *t*, when *wt* means week represented by *t*. The summation of the target cell must equal zero so that the placements for all weeks equal those placed in the month.

These constraints ensure that weekly placements follow the same seasonal pattern as the estimated monthly placements and that total weekly placements for the month equal monthly placements. Weekly placements with the constant value for number of weeks/month will be labeled "WP". The SAS seasonally adjusted weekly placements are labeled throughout the remainder of the study as "SP". Finally the weekly placements calculated as a percentage share in a month are defined as "FP". These three transformations will be estimated in the model.

Table 2.4: Example of Transforming Monthly to Weekly Data using Percentage Method "FP"

| Month | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Total | Percentage | target cell =0 when solved |
|---|---|---|---|---|---|---|---|---|---|
| Jan-13 | 91.80 | 137.29 | 107.87 | 73.84 | 39.20 | 0 | 450 | 0.1361 | 0 |
| Feb-13 | 31.07 | 84.00 | 78.72 | 85.08 | 66.13 | 0 | 345 | 0.2671 | 0 |
| Mar-13 | 23.30 | 89.74 | 94.60 | 95.60 | 93.47 | 13.29 | 410 | 0.2287 | 0 |
| Apr-13 | 78.37 | 87.42 | 84.57 | 83.67 | 35.98 | 0 | 370 | 0.2312 | 0 |
| May-13 | 46.40 | 84.21 | 88.41 | 93.04 | 82.94 | 0 | 395 | 0.2169 | 0 |
| 13-Jun | 9.92 | 72.13 | 73.81 | 74.41 | 74.15 | 10.58 | 315 | 0.1746 | 0 |
| Jul-13 | 76.47 | 87.86 | 87.17 | 87.75 | 50.74 | 0 | 390 | 0.2868 | 0 |

Figure 2.5: Illustration of Three Data Transformations and Estimation Steps

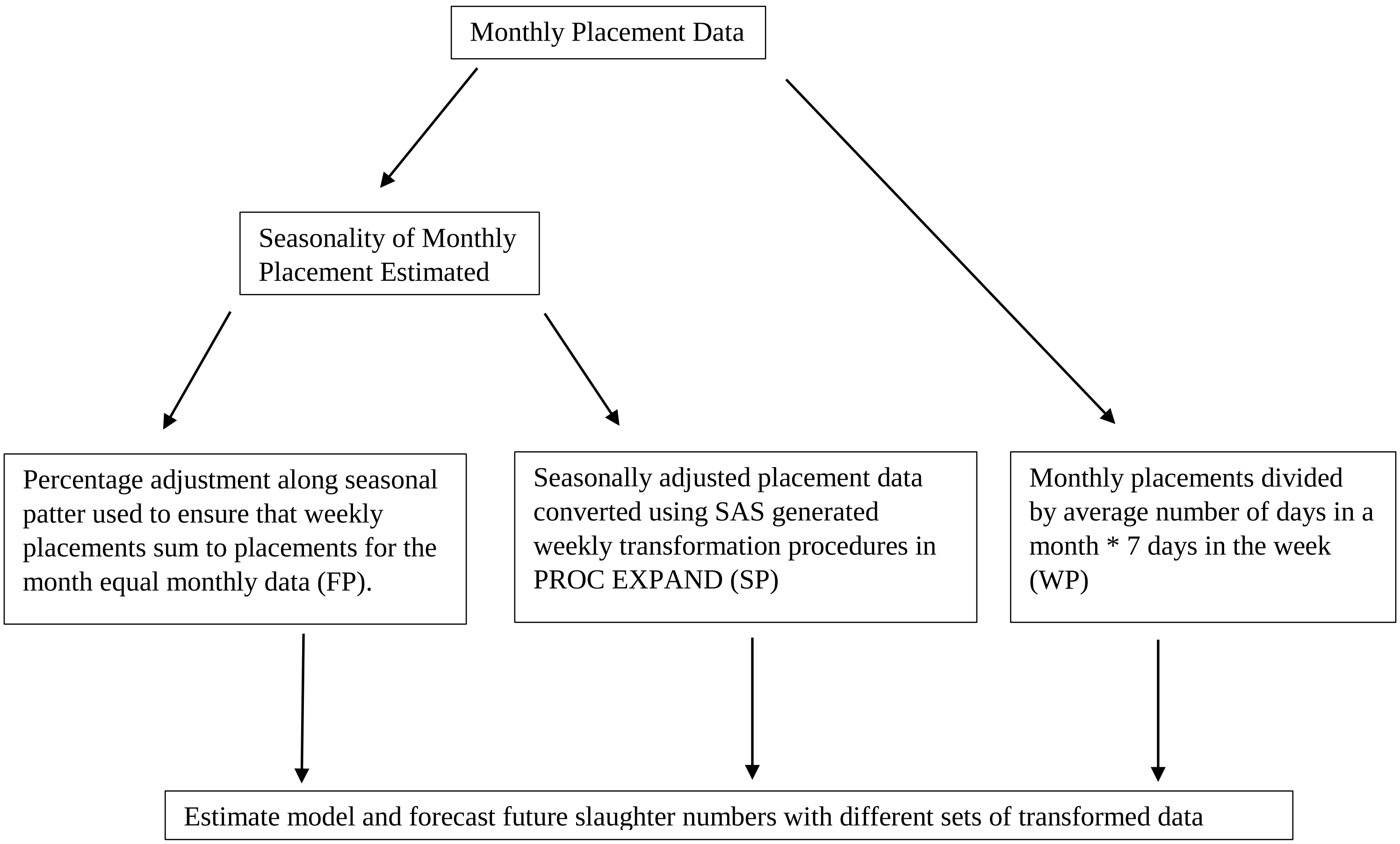


Figure 2.6: Comparison of Three Weekly Placement Transformations, <600 lbs. (Jan. 2000- Dec.2003)

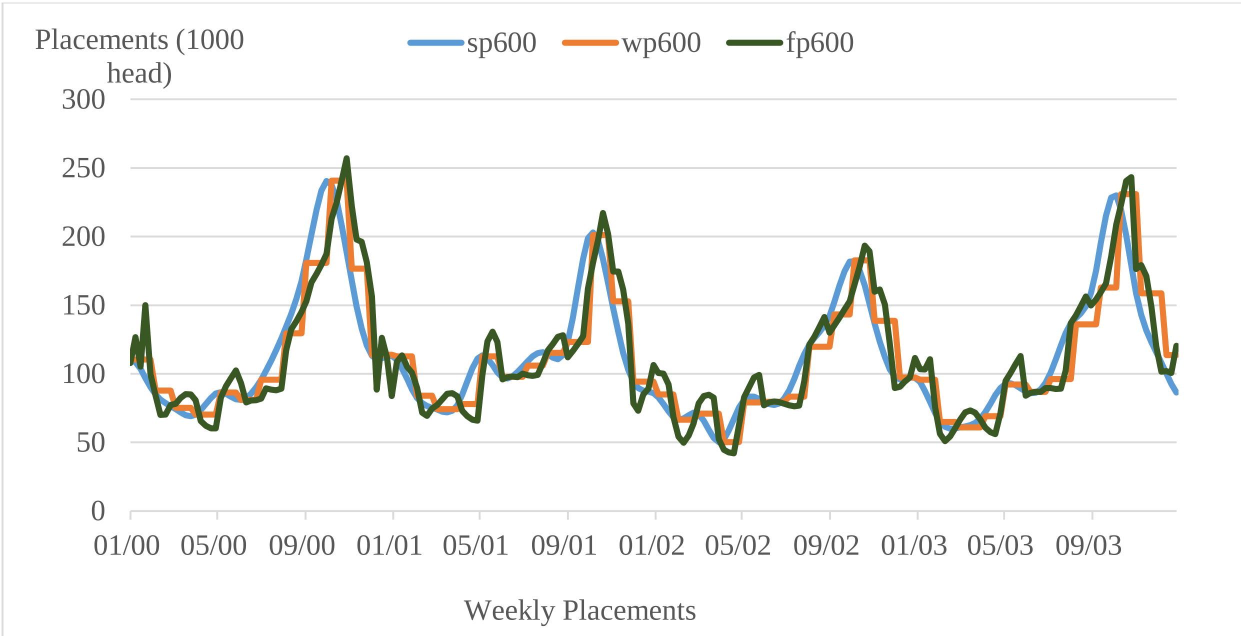
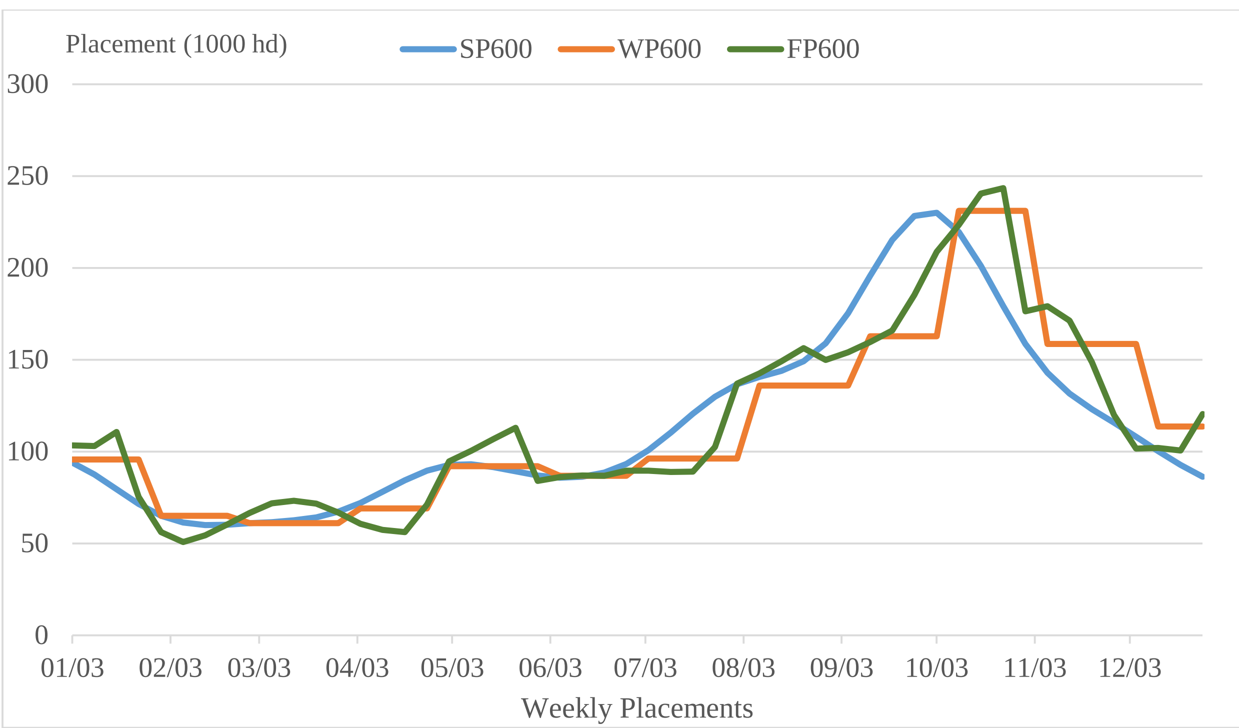



Figure 2.7: Comparison of Three Weekly Placement Data, <600 lbs. (Jan. 2003-Dec 2003)



## Chapter 3: U.S. Feeder Cattle Market:

The model that is used for estimating slaughter numbers is a polynomial distributed lag function of weekly feeder cattle placements from all weight classes, the natural log of the price ratio of fed cattle over corn prices, the choice minus select price spread and price of corn. The polynomial distributed lag (PDL) was chosen because it is expected that these lag relationships to be smooth, fewer parameters are required for estimations, and PDL helps reduce multicollinearity among variables which often occurs in weekly time series data. OLS estimates will have biased standard errors with multicollinearity. To determine the appropriate polynomial degree and lag order we utilize both ranges in ADGs and statistical criteria. The PDL parameterizes the lag coefficients as a function of a few underlying parameters; this approach is practical for estimating the model with long lag lengths (Hill, 2008).

### Lag Length Selection:

One of the most important aspects of the Polynomial Distributed Lag model is determining the appropriate lag length and polynomial order. To get a meaningful starting point for the amount of time cattle are in the feedlot, data from KSU's feedlot publications are utilized to determine an appropriate amount of time it would take to get placements to slaughter weights, in appropriate lag lengths. Average daily gain is not equal across each placement weight category, according to feedlot data from KSU and industry websites such as purinamills.com (Nutrition, 2015). Heavier animals tend to have a higher average daily gain versus the lighter animals. In order to determine the time on feed, the initial weight of the animal is required along with the ADG. In order to get a general understanding from the range of placement weights, the median number is used for the initial weight of each placement class. For the <600 lbs. animals, placement class of feeders, an initial weight of 550 lbs. is presumed. Therefore for this analysis, for every 100 lbs. (decreased) increased from the 600-700 weight (650-lbs. initial weight), 1/10 of a lbs. was (subtracted) added to the specific classes for their ADG (ADG Table (3.1)). Final weights varied due to the various seasonal differences in slaughter weights from the KSU data, the ranges of final weight varied from 1108 to 1344 lbs. These final weights are a weighted average of steer and heifer slaughter weights. Steers are typically slaughtered at heavier weights than heifers. The final weight average slaughter weight for steers from the KSU data was 1274 lbs. while the heifers average slaughter weight was 1173 lbs. To get a more accurate representation of average slaughter weight the percentage of heifers and steers was determined from the KSU feedlot, and this was used to determine a weighted average. The feedlots were found to consist of 60% steers and 40% heifers. The weighted averages of steers and heifers were 1235 lbs. with a minimum of 1108 lbs. and a maximum of 1344 lbs. From the average daily gain, the placement weight, and the range of weight final weights, the number of weeks on feed is determined:

Table 3.1: KSU Average Daily Gain for Four Weight Placement Groups

| Placement Weights | 550 lbs. | 650 lbs. | 750 lbs. | 850 lbs. |
|---|---|---|---|---|
| **Min** | 2.61 | 2.71 | 2.81 | 2.91 |
| **KSU Mean** | 3.11 | 3.21 | 3.31 | 3.41 |
| **Max** | 3.59 | 3.69 | 3.79 | 3.89 |

(3.1): $$weeks\ on\ feed_w = \left[\frac{(final\ weight_k - initial\ weight_i)}{average\ daily\ gain_r}\right] / 7days$$

Where:

*r= average daily gain min, mean, max*

*w= week*

*i=initial weight class = 550, 650, 750, 850 lbs.*

*k= final weight*

Table 3.2: KSU Weeks on Feed for Four Weight Placement Groups

| Placement Weights | <600 lbs. | 600-699 lbs. | 700-799 lbs. | >800 lbs. |
|---|---|---|---|---|
| **Weeks on Feed Max:** | 43.9 | 37.0 | 30.6 | 24.6 |
| **Weeks on Feed Mean:** | 36.7 | 31.1 | 25.9 | 20.9 |
| **Weeks on Feed Min:** | 31.9 | 27.1 | 22.6 | 18.4 |

Empirical Model:

In the model $FITOT_t$ is the total federally inspected slaughter numbers of steers and heifers at time *t*. The four weight classes will be aggregated to represent all the cattle being slaughtered, not just per weight class. $FP_t$ is the weekly placement based on percentage transformation of seasonally adjusted monthly placement, and *i* denotes each of the four feedlot weight placement classes. (<600 lbs., 600 to 699 lbs., 700 to 799 lbs., and >800lbs.). The variable *lnratioslc,* is the log of the ratio between the steer and heifer slaughter price and the spot price of corn. The variable *lntratioccs* is the log of the ratio between the choice minus select spread and the spot price of corn. The variables *holiday* are dummy variables, which include either a one-day holiday or two-day holiday. The letters of $r_i, s, p, and\ q$ are the lag periods in regards to the weekly time period with $\varepsilon_t$ being the error term. For modeling fitting Criteria, the Schwarz Bayesian Criteria were used to aid in helping determine the appropriate lag length and polynomial order for the PDL model.

The model for total federally inspected slaughter numbers is as follows:

(3.2)

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i} \alpha_{ij}\, FP_{i_{t-j}} + \sum_{k=s_1}^{s_2} \beta_k lnratioslc_{t-k} + \sum_{l=p_1}^{p_2} \delta_l\, lnratioccs_{t-l} + \sum_{h=1}^{2}\sum_{o=q1}^{q_2} \gamma_o holiday_{t-o} + \varepsilon_t\ ,$$

*i=1=feeder placements < 600 lbs.*

*i= 2= feeder placements 600-699 lbs.*

*i=3 = feeder placements 700-799 lbs.*

*i=4= feeder placements > 800 lbs.*

*t= week*

*j,k,l= lag length*

*r,s,p,q=total lag period*

*h=1=holiday dummy one day*

*h=2=holiday dummy two day*

Subject to:

$$\alpha_{ij} = \sum_{m=0}^{n} a_{im}\left(\frac{j+1}{P+1}\right)^{n}, \quad \beta_k = \sum_{m=0}^{n} b_m\left(\frac{j+1}{P+1}\right)^{n}, \; and \; \delta_l = \sum_{m=0}^{n} d_l\left(\frac{j+1}{P+1}\right)^{n},$$

$\alpha_j$, $\beta_k$, $\delta_l$ are approximated coefficients for the variables placement, slaughter price/corn relationship, and choice minus select/corn price relationship respectively by a second-degree polynomial (i.e., n = 2) in the length of lags, j,k, and l. Similar to the percentage transformation placement model (equation 3.2), the following models (3.3) and (3.4) are slaughter numbers. An equation for both the non-seasonally transformation placements and the SAS seasonality transformation placements are provided. These models will be estimated to help quantify weekly slaughter numbers and ultimately forecast slaughter numbers and beef production.

(3.3)

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i} \alpha_{ij}\, WP_{i_{t-j}} + \sum_{k=s_1}^{s_2} \beta_k lnratioslc_{t-k} + \sum_{l=p_1}^{p_2} \delta_l\, lnratioccs_{t-l} + \sum_{h=1}^{2}\sum_{o=q1}^{q_2} \gamma_o holiday_{t-o} + \varepsilon_t\,,$$

*i=1=feeder placements < 600 lbs.*

*i= 2= feeder placements 600-699 lbs.*

*i=3 = feeder placements 700-799 lbs.*

*i=4= feeder placements > 800 lbs.*

*t= week*

*j,k,l= lag length*

*r,s,p,q=total lag period*

*h=1=holiday dummy one day*

*h=2=holiday dummy two day*

Subject to:

$$\alpha_{ij} = \sum_{m=0}^{n} a_{im} \left(\frac{j+1}{P+1}\right)^{n}, \quad \beta_k = \sum_{m=0}^{n} b_m \left(\frac{j+1}{P+1}\right)^{n}, \; and \; \delta_l = \sum_{m=0}^{n} d_l \left(\frac{j+1}{P+1}\right)^{n},$$

(3.4)

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i} \alpha_{ij}\, SP_{i_{t-j}} + \sum_{k=s_1}^{s_2} \beta_k lnratioslc_{t-k} + \sum_{l=p_1}^{p_2} \delta_l\, lnratioccs_{t-l} + \sum_{h=1}^{2}\sum_{o=q1}^{q_2} \gamma_o holiday_{t-o} + \varepsilon_t ,$$

*i=1=feeder placements < 600 lbs.*

*i= 2= feeder placements 600-699 lbs.*

*i=3 = feeder placements 700-799 lbs.*

*i=4= feeder placements > 800 lbs.*

*t= week*

*j,k,l= lag length*

*r,s,p,q=total lag period*

*h=1=holiday dummy one day*

*h=2=holiday dummy two day*

Subject to:

$$\alpha_{ij} = \sum_{m=0}^{n} a_{im} \left(\frac{j+1}{P+1}\right)^{n}, \quad \beta_k = \sum_{m=0}^{n} b_m \left(\frac{j+1}{P+1}\right)^{n}, \; and \; \delta_l = \sum_{m=0}^{n} d_l \left(\frac{j+1}{P+1}\right)^{n},$$

Equations 3.3 and 3.4 are the same as equation as 3.2 with the exception being the seasonally transformed weekly placements. Equation 3.3 is determines weekly slaughter numbers by using the weekly placement adjustment (WP). Whereas, equation 3.4 estimates weekly slaughter numbers but uses the seasonally transformed weekly placements from SAS (SP). Comparing the various transformed weekly placements gives different avenues for transforming monthly to weekly placements and estimating slaughter numbers.

Expected relationships between slaughter numbers and other variables:

Price ratio parameters are a part of this model and explain market factors that affect cattle feeding. The rate of gain, in-weight, and final weight explain the amount of time feeders will be in the feedlot but price factors also influence when feeder cattle will go to the packing plant. Consequently, understanding the cost of feed for the animal as well as the price received at the packing plant is important to determine whether the animals leave the feedlot at a heavier weight or not. Parameter associated with the price ratio of fed cattle and corn (gain-cost ratio), would in general be expected to be positive. However, the price ratio combines two economic effects together (fed cattle price and feed costs) and both positive and negative relations to the dependent variable may exist. For example, if the price of fed cattle increases, (the price ratio will increase), feedlot operators would like to send cattle to market soon to gain the benefit of the immediate higher price. Slaughter numbers will then increase; since quantity supplied increases with higher prices. However, higher fed cattle prices may also have the opposite effect, especially for cattle not immediately ready for slaughter as, the return of feeding cattle increases with higher cattle prices. Therefore the increased return for feeding cattle longer will have cattle at higher finished weights and delayed in entering the immediate slaughter market. The same outcome occurs if corn prices increase: as feeding costs increase the return from feeding to a heavier weight decreases, therefore sending current feeders to the market sooner. If cattle feeders have previous corn supplies stored and purchased; this effect may take a few more weeks to see the effect on slaughter numbers. The reaction to the fed cattle slaughter price will be felt quicker than to the change in corn price. Thus, in the current weeks and months the expected relationship between slaughter quantities and the price ratio of fed cattle and spot corn price are anticipated to be positive.

Agricultural markets are volatile due to many seasonal and production factors, when looking at feed costs or slaughter fed price, alternative outcomes need to be looked at. Consider a case when corn prices decline, and the fed steer price remain flat or decrease slightly, the ratio between the two prices will increase but may lead to an opposite fundamental economic reaction. Feedlot operators will keep the cattle in the feedlot due to the lowered corn price and anticipating a change in the fed cattle market price. Again the lower corn price may not have an immediate effect on cattle feeding and slaughter markets. Cattle feeders buy corn to support coming time periods; therefore the lower price of a few earlier periods affects the current market. The price ratio of fed cattle and corn from a few prior weeks is expected to negatively impact current slaughter numbers.

As mentioned earlier, beef quality when slaughtered is an important determinant of profitability for the feedlot operator and cattle producer.  The choice-select spread price measures the price premium between the two quality cuts of beef. Prime is the most desired cut with select being the least desired based upon various taste attributes for consumers.  As quality of the cut increases the prices will increase as well. The relationship of the ratio of this choice-select price spread and corn price to slaughter numbers is similar to that of the fed cattle slaughter price and corn price ratio.

When looking at slaughter numbers over time, the various sharp dips in slaughter occur during national holidays when the packing plants shut down processing. The weeks surrounding holidays such as the two-day holidays during Christmas have a holiday effect on slaughter numbers for the week before and during the holiday. Therefore dummy variables for one-day and two-day holidays are used to capture the “holiday effect” on slaughter numbers.

# CHAPTER 4: EMPRICIAL RESULTS AND FORECASTING

Estimated Results:

The results from the polynomial distributed lag model represent a logical relationship between weekly federally inspected slaughter and placements of feeder cattle. As expected, for placements weights <600 lbs., the placement of 25 to 48 weeks from a given week *t* of slaughter will have a significant effect on slaughter numbers at week *t*. The polynomial function distribution for the parameters in the <600 lbs. placement class is a normal distribution of parameters. The range of 25 to 48 is a wide range, however for the <600 lbs. weight class the amount of time that feeders spending in the feedlot may vary greatly due to entering as a dairy calf at 300 lbs. to a calf near 600 lbs. (i.e. 550 lbs. heavier calf versus 300 lbs. dairy calf). For the placement weight of 600 to 699 lbs., the feeding time is 20 to 37 weeks. For the 700-799 lbs. weight category, placements from 12 to 30 weeks back have a significant impact on slaughter numbers in time *t*. Finally, for the >800 lbs. weight class, weeks 5 to 19 lagged from have a significant effect. For the placement weight class variables, all the parameter estimates are relatively small, positive, and significant. The polynomial distributed lag function is a second order and constrained on both sides. The PDL results in a "U" shaped curve with the majority of the placements occurring in the middle of the span, due to the $2^{nd}$ order PDL. As the weight placement classes increase from <600 lbs. to >800 lbs. the width of the "U" shape is decreasing. As the initial weight increases, the amount of time remaining in the feedlot decreases along with the distribution around the maximum. The normal distribution of weeks that are significant for the placement weight class can be observed for the "FP", "SP" and "WP' weekly transformations in Figures 4.1, 4.2 and 4.3 respectively.

Figure 4.1 displays the PDL results with the lagged weeks and coefficients forming a "U" shaped curve representing the weekly transformed placements "FP" for the four weight classes. The results from Figures 4.1, 4.2, and 4.3 validate the model and present an accurate display of weeks on feed. Figure 4.1 displays that the 700-799 lbs. weight class has the highest coefficient of placements followed by the 600-

699 lbs., the <600 lbs. and >800 lbs. weights have a similar coefficient. The 700-799 lbs. weight class was expected to be the highest coefficients due to the majority of feeder cattle are placed in this weight group. Examining average placement data, the second highest placed weight class is the >800 lbs. followed with <600 lbs. and 600-699 lbs. being similar for third and fourth. Looking at Figure 4.1 the overlaps in the polynomial "U" shape indicates that there are cattle that are placed in their various weight classes but are in the feedlot with similar times as the other weight classes. This overlap is expected because cattle are not expected to have the same ADG or reach their slaughter weight all on the same day. Therefore when determining the lag lengths for each weight class the overlap puts some placements from the neighboring weight classes during the same weeks. Figure 4.1 displays an accurate representation of the actual placement coefficients and lagged weeks (weeks on feed) for the percentage adjustment "FP" placements.

Figure 4.2 is the seasonally adjusted SAS transformations "SP" second-order polynomial function of estimated coefficients. Using the Schwarz Criteria, the appropriate lag lengths and polynomial order was determined for each of the different data transformations. For the "SP' data, the lag lengths were shifted for the outer edge weight classes (i.e. <600 lbs. and >800 lbs.). Shifting the lag lengths wider resulted in a better Schwartz Criteria value and thus resulted in the appropriate coefficient polynomial functions that are believed to describe the appropriate placements. The 700-799 lbs. weight class has the highest coefficients while the 600-699 lbs. has the second highest coefficients; the other two weight classes have similar coefficient values in all of the figures.

Figure 4.3 is the seasonally adjusted fixed placement transformations "WP" 2nd-rder polynomial function of estimated coefficients. As displayed in the first two figures, the "U" shaped polynomial function is distributed over the various lag lengths for the weight classes. The lag lengths for the "WP" data are the same as the "FP" data. Figure 4.3 presents the most profound results for the placement polynomial function. The 700-799 lbs. weight group has the highest coefficient with the 600-699 lbs.

class with the second highest, followed in third by the >800 lbs. weight class, and finally the <600 lbs. weight class.

All three of the data transformations results display a similar distribution of coefficients. The Figures 4.1, 4.2, and 4.3, display that each data transformation can be used to determine the amount of weeks that cattle are on feed.

Figure 4.1: 2nd-order Polynomial Function of Estimated Coefficients for Placement Class using Percentage Adjusted “FP” data.

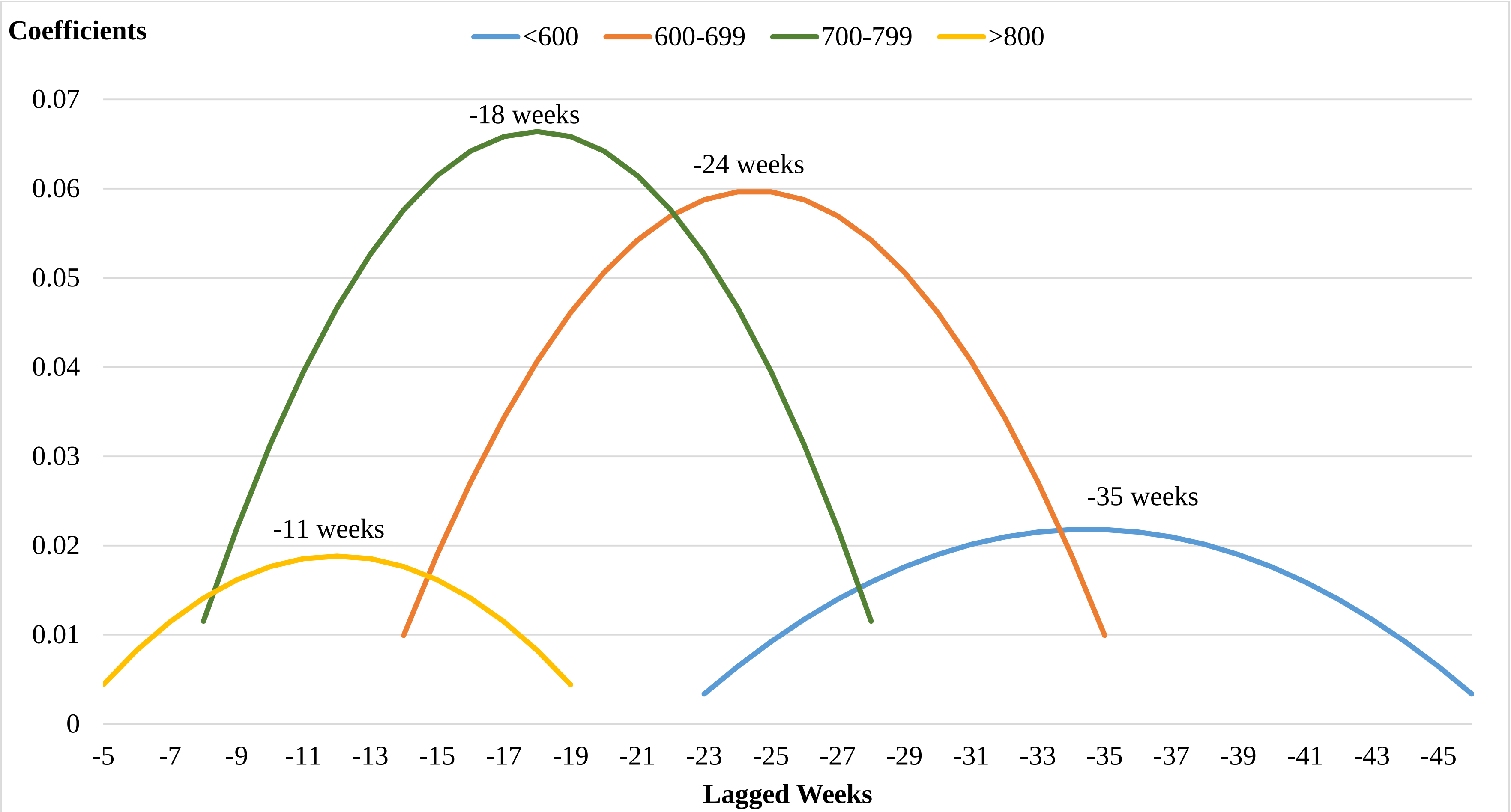


Figure 4.2: 2nd-order Polynomial Function of Estimated Coefficients for Placement Class using Seasonally Adjusted SAS “SP” data.

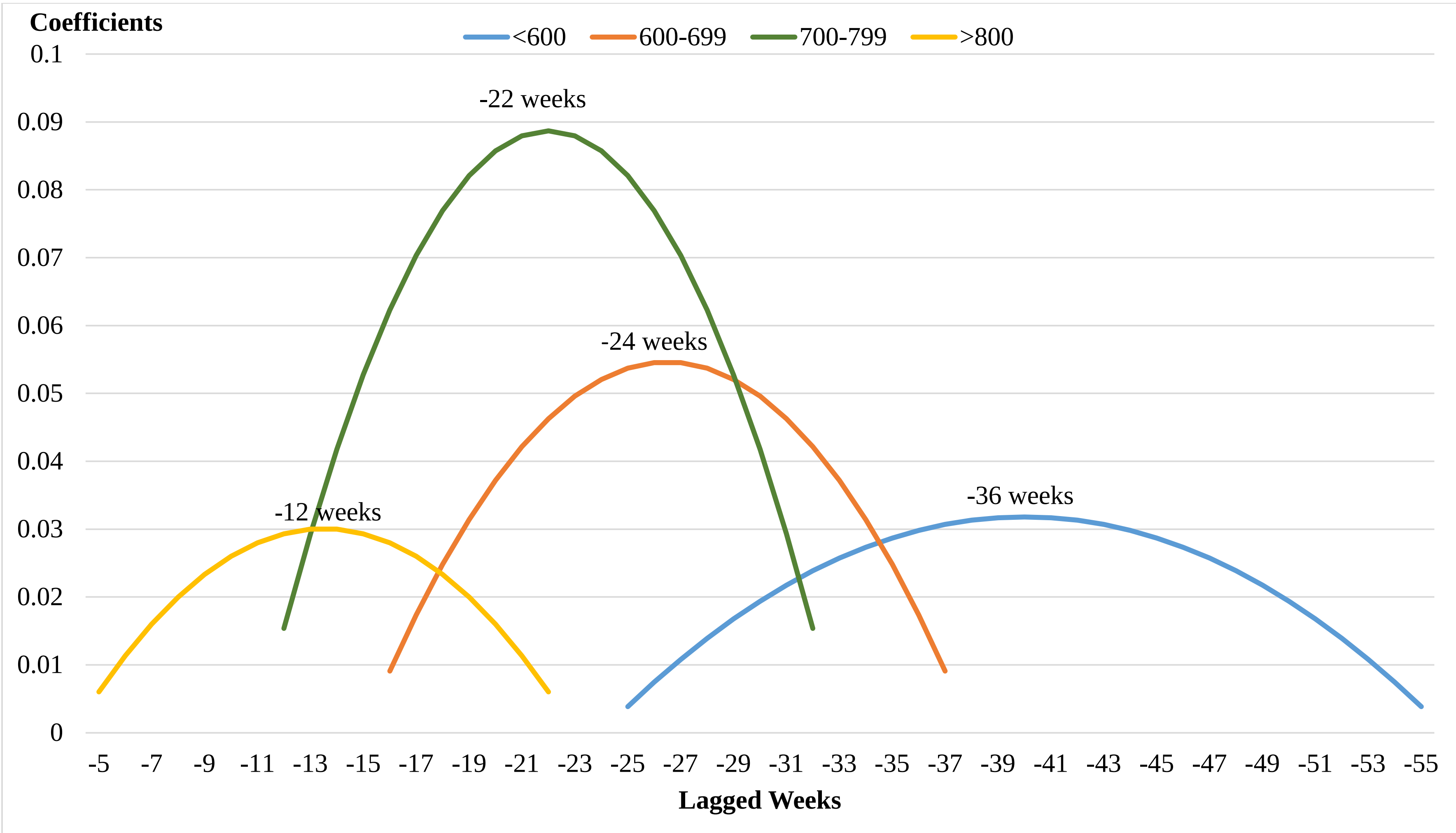
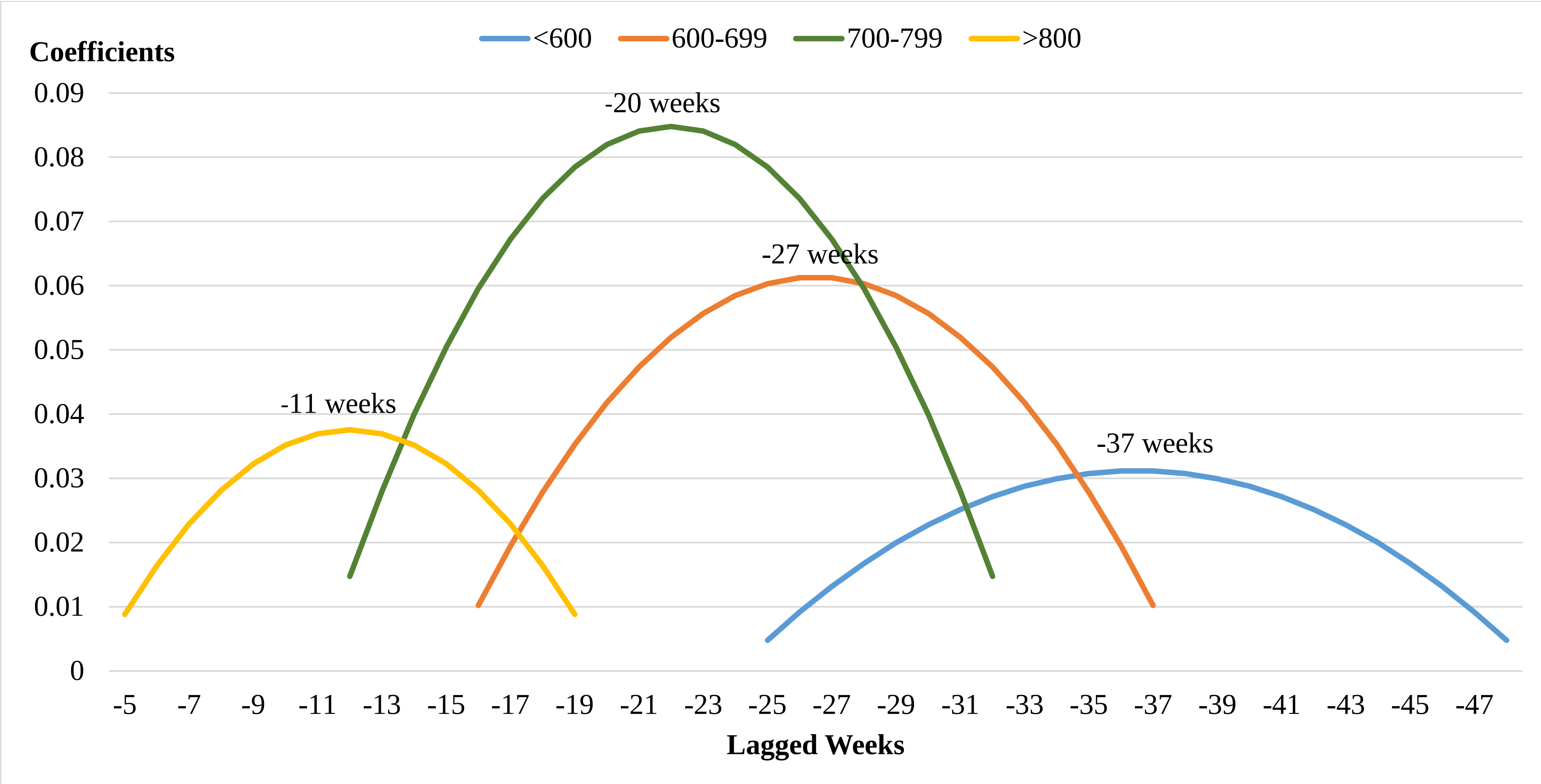


Figure 4.3: 2nd-order Polynomial Function of Estimated Coefficients for Placement Class using Fixed Placement "WP" data.



Overall, the results of the three data transformations for determining the amount of weeks on feed using the PDL model were successful. The figures display the amount of time with the "U" shaped polynomial functions are logically and in line with the actual placement data. From using the same amount of lagged weeks, the model presents similar results with the exception of the "SP" data. This group has a different distribution but when adjusted on the outside weight groups, it displays similar results to the other two groups. This could be explained due to SAS's seasonality adjustment procedures, when looking at the seasonally adjusted data. SAS's transformations are the smoothest and peak at different times versus the other two groups (Figure 2.6). In order to determine the optimal lag lengths, a selection criteria needs to be established. In defining lag lengths, number of weeks on feed determined from the KSU data was used as a starting point, and then adjusted using the Schwarz Criteria to conclude the appropriate lag lengths. These figures present an accurate representation of the polynomial distributed lag model's results in determining the amount of weeks on feed for each placement class.

By following the statistical criteria of Schwartz Criteria or BIC, it was determined the best fitting lag lengths and polynomial orders for the placement classes. From the amount of time feeders spend in the feedlot, we are able to compare the ADG values for U.S. beef production versus that of the KSU feedlot data. It would be expected that the ADG from KSU and these estimated ADG's should be similar. However with the lengths of time determined from this analysis, the ADG ranges are much wider compared to KSU's feedlot data. ADG's for the greater than 800 lbs. group calculated to be well above what is biologically possible using a final slaughter weight of 1350 lbs.. This error was due to The reason for the extreme ADG's is due to the unknown actual slaughter weights The means of the ADG are relatively on par but in the maximum rate of gain categories, these values are vastly exaggerated and demonstrate the variability that occurs. Intuitively that is justified due to the greater variability in feedlot placements, feeder genetics, region, and climate throughout the U.S. compared to Kansas.

In terms of the price ratio variables, the results were mixed and have different outcomes for interpretation. The price ratio between the fed steer price and corn price have a negative relationship for the current few weeks and then change to a positive sign for a further back. In the current period, a high fed price has a negative impact on slaughter due to feedlot operators holding back cattle to be marketed at heavier weights due to higher returns from feeding. The change from negative to positive indicates that immediate slaughter is negatively impacted due to fed cattle price and feed costs but eventually the feeders reach the desired slaughter weight and are sold.

For the choice minus select and corn price ratio, the immediate effect has a positive impact on slaughter while in the later weeks a negative impact. When the choice minus select ratio is high, the immediate reaction by feedlot operators seems to be to sell cattle to take advantage of the higher price. Heavier cattle are more likely to grade choice than lighter cattle given all other things equal. As time progresses, the ability to sell cattle diminish since feedlots have already responded to the higher price signal. Therefore, the later weeks have a negative impact on slaughter when choices minus select ratios are high. For the holiday variables, there is a significant drop in slaughter for one-day holidays and an even greater drop over times that of the one-day holiday for two-day holidays. The holiday dummy's results were highly significant in determining the drop in slaughter for those weeks.

Table 4.1: Estimate Results of the Polynomial Distributed Lag Model using Percentage Adjustment "FP" Data

| | | | |
|---|---|---|---|
| **# of observations** | 993 | **Mean Square Error** | 802.6346 |
| **Mean of Dep. Variable** | 527.927609 | **R-Square** | 0.62 |
| **Std. Dev. Of Dep. Var.** | 45.3167615 | **Schwartz BIC** | 8102.803 |
| **Sum of Squared Errors** | 668594.576 | **Durbin-Watson** | 1.3625 |

| Variables | Estimate | Standard Error | Variables | Estimate | Standard Error |
|---|---|---|---|---|---|
| FP600(-25) | 0.003867*** | 0.00042 | FP699(-16) | 0.011093*** | 0.000925 |
| FP600(-26) | 0.007412*** | 0.000805 | FP699(-17) | 0.021177*** | 0.001766 |
| FP600(-27) | 0.010634*** | 0.001155 | FP699(-18) | 0.030253*** | 0.002522 |
| FP600(-28) | 0.013534*** | 0.001469 | FP699(-19) | 0.038321*** | 0.003195 |
| FP600(-29) | 0.016112*** | 0.001749 | FP699(-20) | 0.04538*** | 0.003783 |
| FP600(-30) | 0.018368*** | 0.001994 | FP699(-21) | 0.051431*** | 0.004288 |
| FP600(-31) | 0.020301*** | 0.002204 | FP699(-22) | 0.056473*** | 0.004708 |
| FP600(-32) | 0.021912*** | 0.002379 | FP699(-23) | 0.060507*** | 0.005044 |
| FP600(-33) | 0.023201*** | 0.002519 | FP699(-24) | 0.063532*** | 0.005297 |
| FP600(-34) | 0.024168*** | 0.002624 | FP699(-25) | 0.065549*** | 0.005465 |
| FP600(-35) | 0.024813*** | 0.002694 | FP699(-26) | 0.066557*** | 0.005549 |
| FP600(-36) | 0.025135*** | 0.002729 | FP699(-27) | 0.066557*** | 0.005549 |
| FP600(-37) | 0.025135*** | 0.002729 | FP699(-28) | 0.065549*** | 0.005465 |
| FP600(-38) | 0.024813*** | 0.002694 | FP699(-29) | 0.063532*** | 0.005297 |
| FP600(-39) | 0.024168*** | 0.002624 | FP699(-30) | 0.060507*** | 0.005044 |
| FP600(-40) | 0.023201*** | 0.002519 | FP699(-31) | 0.056473*** | 0.004708 |
| FP600(-41) | 0.021912*** | 0.002379 | FP699(-32) | 0.051431*** | 0.004288 |
| FP600(-42) | 0.020301*** | 0.002204 | FP699(-33) | 0.04538*** | 0.003783 |
| FP600(-43) | 0.018368*** | 0.001994 | FP699(-34) | 0.038321*** | 0.003195 |
| FP600(-44) | 0.016112*** | 0.001749 | FP699(-35) | 0.030253*** | 0.002522 |
| FP600(-45) | 0.013534*** | 0.001469 | FP699(-36) | 0.021177*** | 0.001766 |
| FP600(-46) | 0.010634*** | 0.001155 | FP699(-37) | 0.011093*** | 0.000925 |
| FP600(-47) | 0.007412*** | 0.000805 | | | |
| FP600(-48) | 0.003867*** | 0.00042 | | | |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | **Variables** | **Estimate** | **Standard Error** |
| FP799(-12) | 0.011492*** | 0.000658 | FP800(-5) | 0.007138*** | 0.001265 |
| FP799(-13) | 0.02189*** | 0.001253 | FP800(-6) | 0.013325*** | 0.002362 |
| FP799(-14) | 0.031193*** | 0.001786 | FP800(-7) | 0.01856*** | 0.00329 |
| FP799(-15) | 0.039401*** | 0.002256 | FP800(-8) | 0.022843*** | 0.004049 |
| FP799(-16) | 0.046515*** | 0.002663 | FP800(-9) | 0.026174*** | 0.00464 |
| FP799(-17) | 0.052535*** | 0.003007 | FP800(-10) | 0.028553*** | 0.005062 |
| FP799(-18) | 0.05746*** | 0.003289 | FP800(-11) | 0.029981*** | 0.005315 |
| FP799(-19) | 0.061291*** | 0.003509 | FP800(-12) | 0.030457*** | 0.005399 |
| FP799(-20) | 0.064027*** | 0.003665 | FP800(-13) | 0.029981*** | 0.005315 |
| FP799(-21) | 0.065669*** | 0.003759 | FP800(-14) | 0.028553*** | 0.005062 |
| FP799(-22) | 0.066216*** | 0.003791 | FP800(-15) | 0.026174*** | 0.00464 |

| | | | | | |
|---|---|---|---|---|---|
| FP799(-23) | 0.065669*** | 0.003759 | FP800(-16) | 0.022843*** | 0.004049 |
| FP799(-24) | 0.064027*** | 0.003665 | FP800(-17) | 0.01856*** | 0.00329 |
| FP799(-25) | 0.061291*** | 0.003509 | FP800(-18) | 0.013325*** | 0.002362 |
| FP799(-26) | 0.05746*** | 0.003289 | FP800(-19) | 0.007138*** | 0.001265 |
| FP799(-27) | 0.052535*** | 0.003007 | | | |
| FP799(-28) | 0.046515*** | 0.002663 | | | |
| FP799(-29) | 0.039401*** | 0.002256 | | | |
| FP799(-30) | 0.031193*** | 0.001786 | | | |
| FP799(-31) | 0.02189*** | 0.001253 | | | |
| FP799(-32) | 0.011492*** | 0.000658 | | | |
| FP799(-33) | 0.011093*** | 0.000925 | | | |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | **Variables** | **Estimate** | **Standard Error** |
| lnratioslc(-1) | -3.787047 | 4.8231 | lnratioccs(-1) | 5.065083*** | 0.8268 |
| lnratioslc(-2) | -2.842241 | 3.0874 | lnratioccs(-2) | 3.267707*** | 0.557 |
| lnratioslc(-3) | -2.01754 | 1.6493 | lnratioccs(-3) | 1.737713*** | 0.3521 |
| lnratioslc(-4) | -1.312946 | 0.671 | lnratioccs(-4) | 0.475102** | 0.2446 |
| lnratioslc(-5) | -0.728457 | 0.8766 | lnratioccs(-5) | -0.520126** | 0.2537 |
| lnratioslc(-6) | -0.264074 | 1.4638 | lnratioccs(-6) | -1.247971*** | 0.3099 |
| lnratioslc(-7) | 0.080203 | 1.8611 | lnratioccs(-7) | -1.708433*** | 0.3534 |
| lnratioslc(-8) | 0.304374 | 2.0111 | lnratioccs(-8) | -1.901512*** | 0.3645 |
| lnratioslc(-9) | 0.408439 | 1.9025 | lnratioccs(-9) | -1.827208*** | 0.3365 |
| lnratioslc(-10) | 0.392399 | 1.532 | lnratioccs(-10) | -1.485522*** | 0.2671 |
| lnratioslc(-11) | 0.256252 | 0.8981 | lnratioccs(-11) | -0.876452*** | 0.1551 |
| | | | | | |
| **Variables** | **Parameter Estimate** | **Standard Error** | | | |
| h1day | -39.5063*** | 3.3744 | | | |
| h2day | -90.8199*** | 7.108 | | | |

(Note: Single asterisks denote significance at the 10% level; double asterisks denote significance at the 5% level; triple asterisk denote significance at 1% level; no asterisks means not significant at all.)

Forecasting Results:

One of the main objectives of this study was to quantify the relationships between monthly placement, weekly slaughter, and average daily gain. The results of the three estimated slaughter numbers model prove that there is a definite relationship between these variables. The next step in utilizing this relationship is done in the form of forecasting. Forecasting is a useful tool because it will validate the estimated models of the three weekly data transformations as well as potentially provide a tool that can be used to gain insight into future slaughter numbers and beef production.

The forecasting procedures were utilized in TSP, an econometric software package, which specializes in the utilization of time-series analysis. The PDL models for each data transformation are estimated for the time period of December 1995 to December 2012. The model estimation results came out slightly different due to the model estimation methods in SAS maybe different than TSP but no major changes are observed in the Schwartz Criteria or other model fitting criteria. 12- and 26-week forecasts are performed, which means using the estimated results to forecast what the slaughter amount and total beef production are for 12 and 26 weeks in the future respectively. Current data are available, that were not estimated (i.e. January 2013 - December 2014). These two years of data are used to validate the forecasting model.

The first estimation is done by using the seventeen years of data from December 1995 - December 2012, and then adding one more week of data to estimate and forecast with the updated data for 12 and 26 weeks periods. The loop process is done continuously to the end of the forecasting period. Figures 4.4 and 4.5 display the comparison of the actual weekly slaughter numbers to the three sets of 12-week and 26-week forecasting results respectively by using different weekly placements (FP, SP, and WP). FP and SP data transformations are smoothly adjusted from monthly to weekly data. Figures 4.4 and 4.5 display that that the three data transformations forecast fairly well, because all three methods are such that the weekly total for each month are almost the same (seasonal adjusted vs. non-adjusted monthly placements) and all the other variables are the same, the three sets of prediction results are very close to each other.

It is difficult to tell which set of weekly data estimate and forecast better since for the graphs for each prediction lies very close to each other. Tables 4.3 and 4.5 compares the root mean square error (RMSE) for the 12 and 26 forecasts using the three sets of placement data. RMSE quantifies the amount by which an estimator differences from the true value of the quantity being estimated, a smaller RMSE is preferred. For the total slaughter numbers forecast, the 12 week forecast has a better fit than the 26 week forecast, with the SP data transformation is the closest prediction to the actual slaughter numbers (Tables 4.3 and 4.4). It is common for all three RMSE values to increase as the forecasting length increases. This is clear due to the fact that it is more difficult to forecast events farther out in time.

A different story can be told for the total beef production forecasting. As mentioned earlier in the study, measuring total beef production is a proxy by multiplying steer and heifer slaughter with their respective average dressed weights. The RMSE values for total production forecasts are less for the 12-week forecast versus the 26-week forecast. The expectation was that the results would be similar to the slaughter forecasts, that the shorter forecasting periods would yield better RMSE results. Explaining the difference in forecasting results for total slaughter and total production is possibly due to the gradual decrease in slaughter numbers over time and production stays relatively consistent throughout the time-series. These differences in the dependent variable maybe the drivers in determine the accuracy of the forecasting period. The forecasts overall provide a good validation of the quantifying of the weekly slaughter numbers from weekly placements and gives a good proxy for estimating total beef production.

Figure 4.4: Comparison of Actual Slaughter Numbers and Three Data Transformation 12 Week Predictions (Jan. 13- Dec. 14)

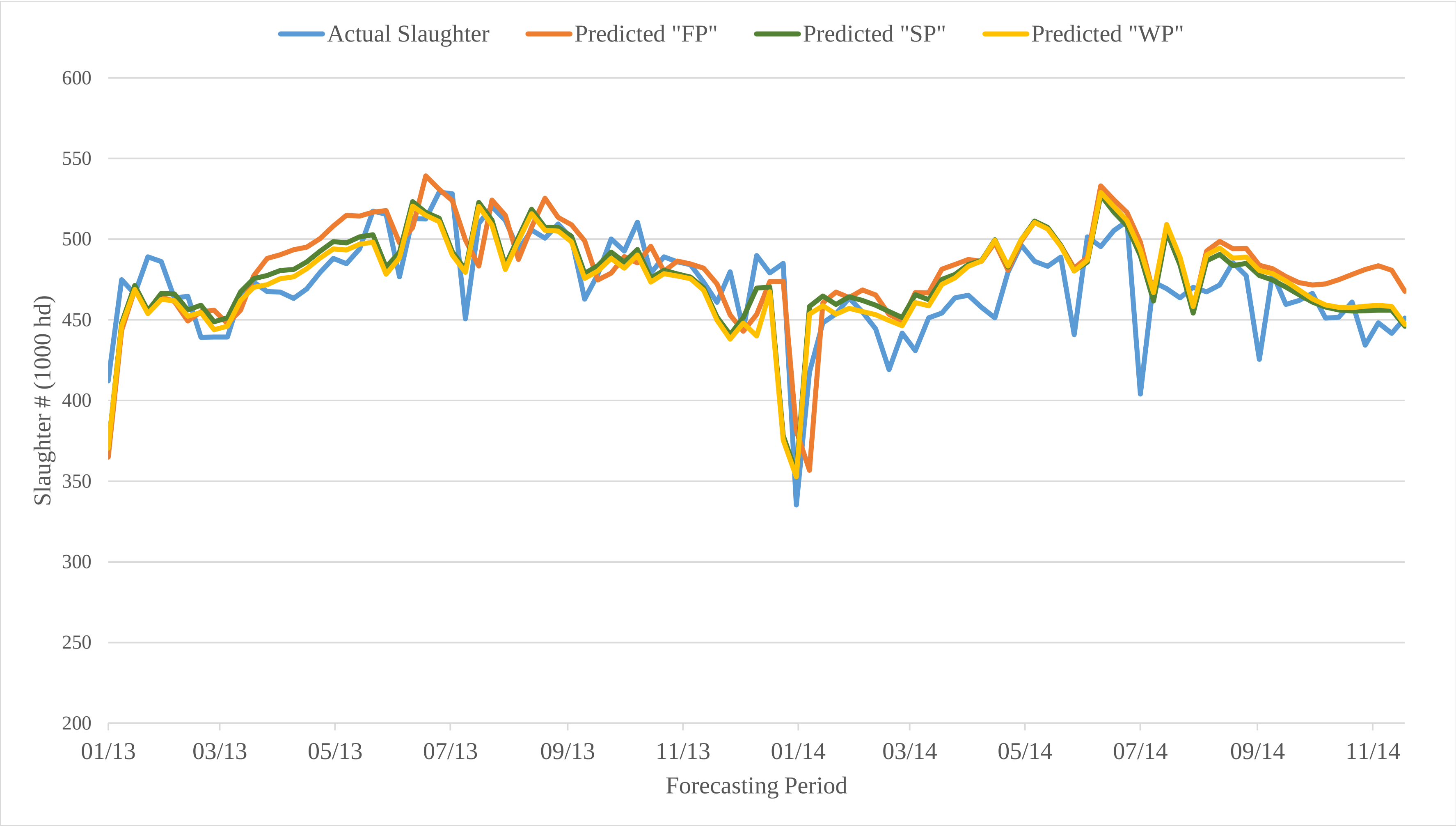


Figure 4.5: Comparison of Actual Slaughter Numbers and Three Data Transformation 26 Week Predictions (Jan. 13- Dec. 14)

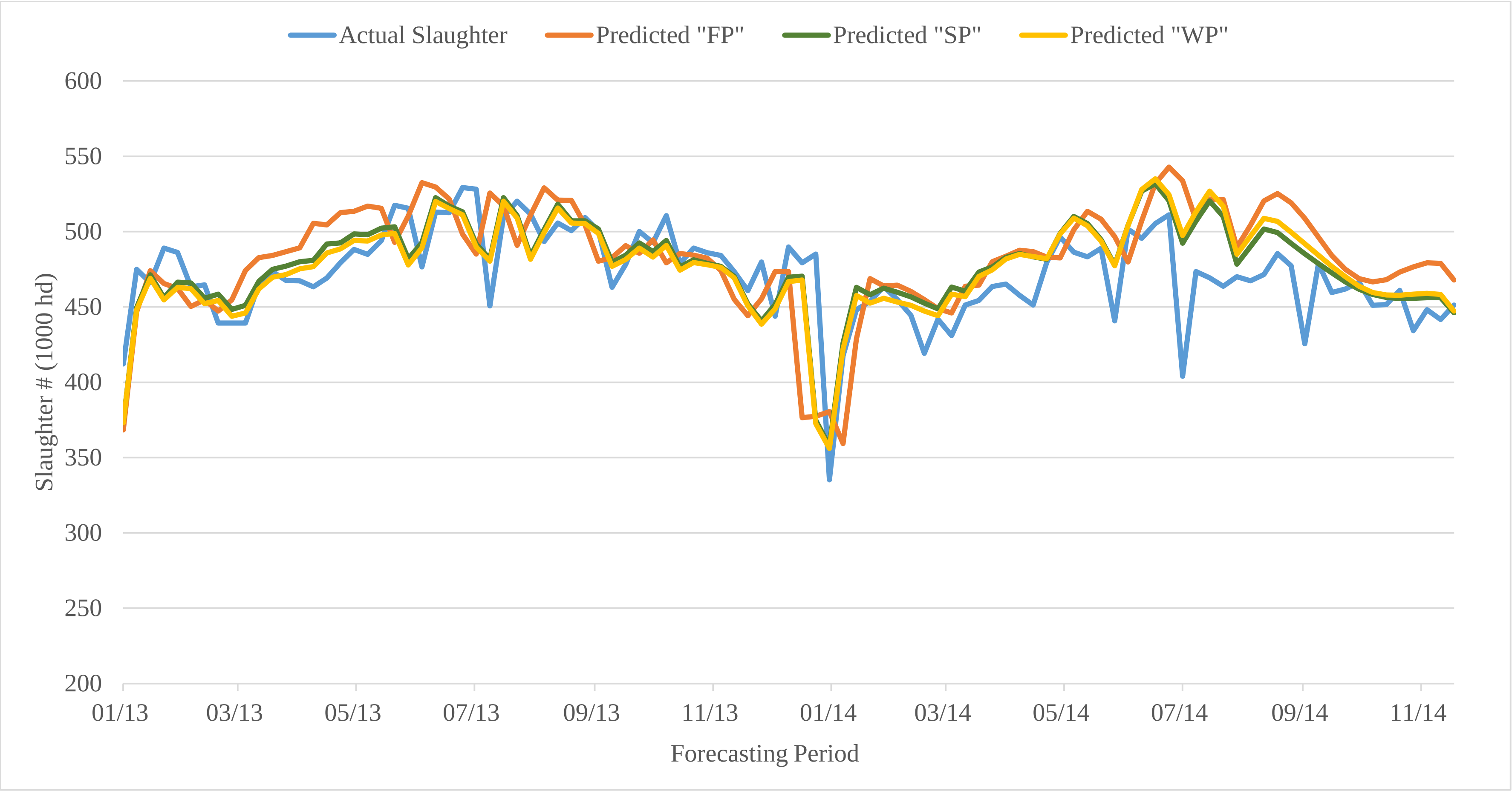


Figure 4.6: Comparison of Actual Total Production and Three Data Transformation 12 Week Predictions (Jan. 13- Dec. 14)

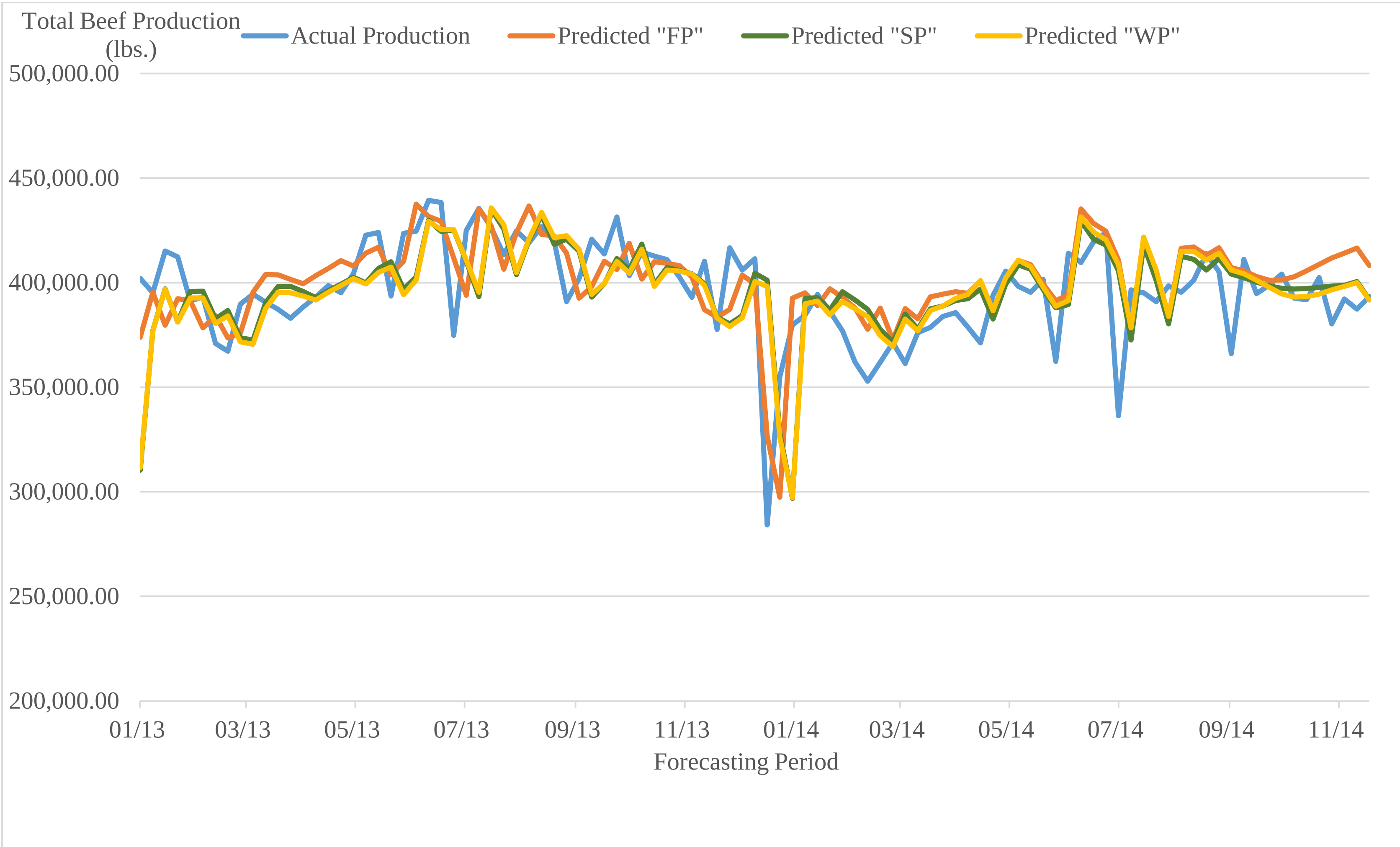


Figure 4.7: Comparison of Actual Total Production and Three Data Transformation 26 Week Predictions (Jan. 13- Dec. 14)

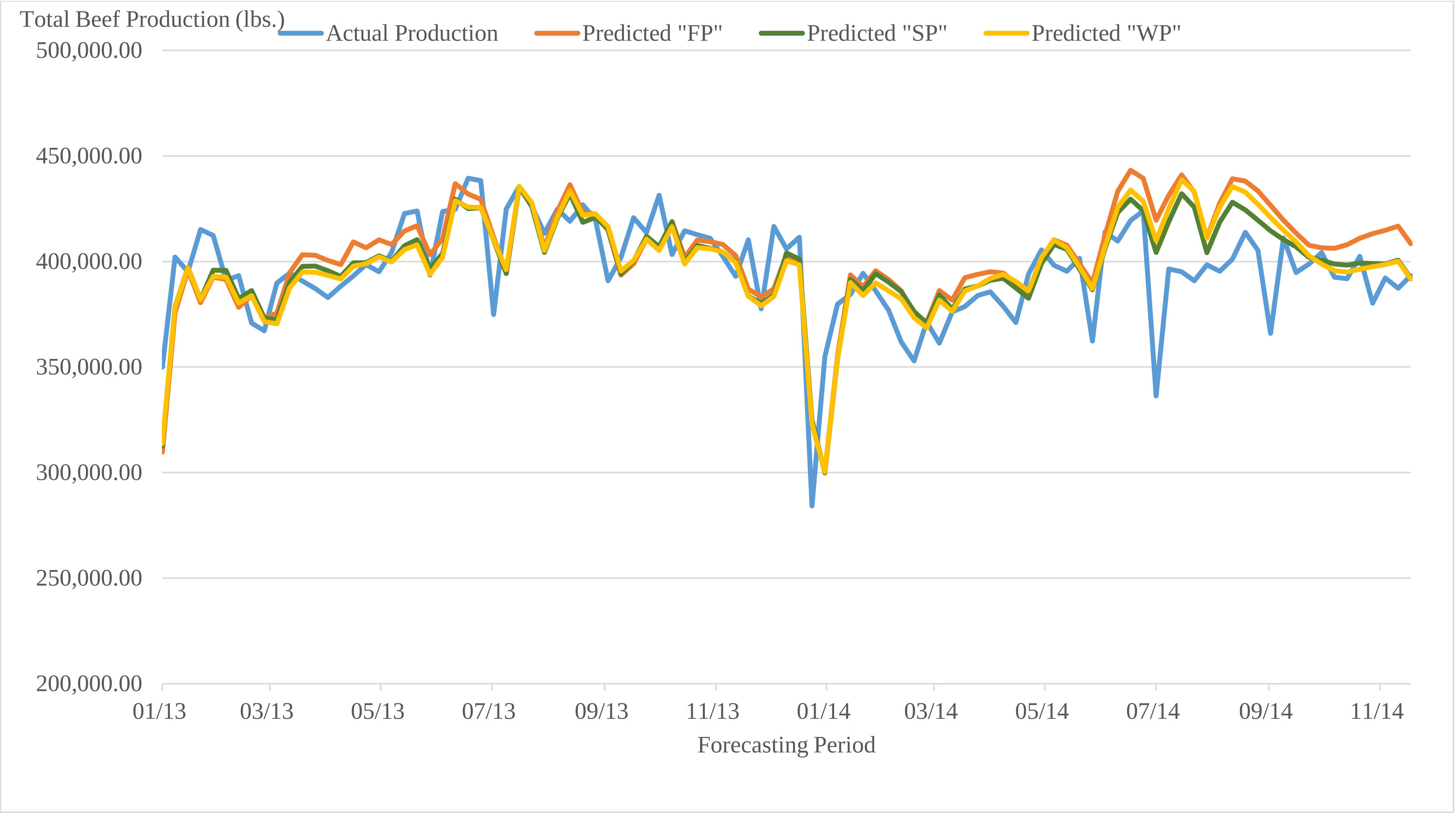


Table 4.2: RMSE by using Different Weekly Placement for Slaughter Numbers Forecast

| Forecasting | FP | SP | WP |
|---|---|---|---|
| **12 Week** | 25.17 | 23.28 | 23.97 |
| **26 Week** | 34.54 | 23.99 | 25.08 |

Table 4.3: Percentage of RMSE to the Mean of Weekly Placement for Slaughter Numbers Forecast

| Forecasting | FP | SA | WP |
|---|---|---|---|
| **12 Week** | 5.34 % | 4.94 % | 5.09 % |
| **26 Week** | 7.33 % | 5.09 % | 5.32 % |

Table 4.4: RMSE by using Different Weekly Placement for Total Beef Production Forecast

| Forecasting | FP | SP | WP |
|---|---|---|---|
| **12 Week** | 25,639.26 | 24,826.61 | 24,742.60 |
| **26 Week** | 21,853.58 | 18,572.83 | 19,663.25 |

Table 4.5: Percentage of RMSE to the Mean of Weekly Placement for Total Beef Production Forecast

| Forecasting | FP | SA | WP |
|---|---|---|---|
| **12 Week** | 6.47 % | 6.26 % | 6.24 % |
| **26 Week** | 5.52 % | 4.69 % | 4.96 % |

# CHAPTER 5: CONCLUSION

A clear relationship between placement numbers, seasonality, ADG, and price factors that determine future slaughter numbers was established in this analysis. The results provide information on how cattle feeders adjust feeding activities and respond to market factors in sending cattle to the slaughter market. As expected, feedlots respond to market signals when deciding whether to market at lighter or heavier weights, the results conclude that variability in cattle feeding and pricing allows for feedlot operators to respond to market fluctuations.  This suggests that cattle feeders have a "window" of selling cattle depending upon the various market factors and slaughter weights.

Seasonality was considered when transforming monthly placements to weekly slaughter.  There is strong seasonality in placement data for all four-weight classes, especially compared against the slaughter data, which mainly displays holiday effects. ADG also shows a strong seasonal component. This is an area where further research can be improved upon as in understanding the seasonal factors influencing ADG. One of the contributions of this study was to quantify the relationship between ADG and slaughter numbers. There was success in determining that seasonal ADG does ultimately have an effect on the amount of time cattle are in the feedlot, which is obvious looking at the KSU feedlot closeouts.  However, the window by which ADG was determined ranged widely from 1.79 lbs. /day to 5.95 lbs. / day. Potential exists for using other explanatory variables that can be used to reduce the wide lag lengths for weeks on feed for the various placement weight categories. It was anticipated that the KSU feedlot data would provide a narrower window of weeks on feed than for the U.S. due to a more uniform sample of cattle being fed in the feedlot and having similar feeding characteristics.  KSU's feedlot data compared to the wide variety of feedlot operations overall for the U.S. indicates that there is a large amount of variability in feedlot operations with differences ranging from cattle genetics to regional weather.

For more accurate beef production results, seasonality can be considered when estimating the average dressed weights and utilizing dressed weight percentages of steers and heifers that can be added into determining total beef product.  There is seasonality in the average dressed weights for steers and heifers, as well as a general upward trend in dressed weights.  This trend makes sense when looking at total production and slaughter numbers as over time slaughter numbers have decreased, as production stays relatively consistent.  Further analysis into determining the variables that influence total beef production may yield more outlooks into the beef industry than just solely predicting slaughter numbers.

There are potential research opportunities by improving econometric and forecasting procedures for this analysis. One area that can improve this study is optimizing lag lengths and polynomial order for estimating the PDL model.  There are large combinations of lag lengths that can be used in determining the PDL model estimates; therefore optimization techniques can be used for this analysis. Transforming monthly placements to weekly placements can be further improved.  Percentage adjustment and SAS seasonally adjusted data were successful for this analysis but there is still variation and not raw weekly placement data.  Obtaining daily slaughter data from packing plants would be useful for validating the monthly to weekly transformations, similar to the KSU feedlot data and determining average daily gain. The daily slaughter data could be used as a validating of the data transformation.

It was found that the PDL model was a strong tool in estimating weeks on feed with accuracy as well for determining price ratio relationships and interpreting how short-term cattle feeders react to market factors. The results were significant for determining weeks on feed. This was expected since a solid understanding of the range in ADGs and model fitting criteria was presented to help determine the amount of time on feed. Results were as expected with the <600 lbs. having the widest range of weeks on feed and gradually decreasing to the > 800 lbs. weight class that had the smallest range of weeks on feed. These ranges make intuitive sense based upon the understanding of ADG and animal growth. Multicolliniearity is relevant in this study due to the weekly time series of the data estimated. Methods could be added to reduce multicollinearity in the model by possibly aggregating slaughter data into monthly aggregates.  One of the main contributions of this analysis is to quantify how placement weights affect cattle flows into and out of the feedlot and determine final beef production.  As mentioned previously, areas that can be improved upon or other explanatory variables that will help in determine the wide weeks on feed ranges and reducing the variability of this component across all the weight placement groups.

Results also indicate the degree of short-term marketing decisions prices have for cattle feeders. The log relationships of overall fed cattle price and quality premiums give insight into marketing decisions of feedlot operators. The log relationship of fed cattle price and corn price give an overall market price received for cattle with relative feed costs. It demonstrates that if cattle are ready for slaughter and the fed price to feed costs ratio is high, then cattle will be sold in the immediate term or if the fed cattle ratio is higher in the future, then feedlot operators will hold off on selling for a few more weeks. The quality premium and feed cost ratio provides a quality measure for the fed price market. The higher the choice minus select ratio results in cattle being sold currently, due to as cattle get heavier, cattle tend to grade more choice along with a high fed steer cattle price ratio, this is a good outcome for the feedlot operator. These results indicate that feedlot operators will market their cattle based on fed cattle price ratios and quality premiums. As slaughter numbers continue to decrease and average dressed weights continue to increase it will be interesting to observe the future short-term marketing decisions using the fed price ratio and quality ratios and how feedlot operators market their cattle.

Transforming monthly placements to weekly placements was a main contribution of this thesis. The seasonally adjusted weekly data allows for a more granular look into the feedlot placement numbers and how that aligns with weekly slaughter. All three of the methods used to transform monthly to weekly data were successful for this analysis. Statistically they all give a similar representation to the amount of weeks that feeders will spend in the feedlot depending upon placement weight. The SAS and Percentage adjusted seasonal transformations provided the smoothest seasonally adjusted placement data. Further research and methods can be applied into predicting weekly slaughter numbers with more accurate disaggregating monthly placements to weekly placements. Using the seasonality component provided a fairly accurate representation of the weekly placement, however further analysis into whether the placement occurred in the beginning or end of the week would allow for a better quantifying of the placement information and adjusting for seasonality. These transformations may be useful in an industry setting due to their ease of adaptation and providing a sound method for adjusting for seasonality in USDA feeder placement data.

The forecasting analysis provides a strong contribution and validation of the PDL model that was estimated for each of the data transformations. The results from the RMSE scores indicate an accurate forecast of slaughter numbers, however the forecasting results tend to not fall into the troughs when actual slaughter decreases due to holidays and be above actual slaughter numbers later in the two-year time horizon. The accuracy of the forecast was expected to reduce farther out in time for the 12 and 26-week forecasts of total slaughter numbers. 12 and 26 week predications are relevant for cattle feeding due to cattle being in feedlots for relatively long periods of time and short term forecasts may be useful but not useful for long term planning for feedlots and packing plants. Much of the same can be said for the total production forecasts. The RMSE scores indicate an accurate forecast of total production, the difference being that the 26-week forecasts have better results. The total productions forecast does not fully decrease when actual production decreases and overshoots actual production numbers at various points. As mentioned in the results, the two differences in accuracy for the slaughter forecast and total production forecast maybe due to that slaughter numbers overall are decreasing through time and that total production continues to be consistent. Improving the proxy for total production should result in decreasing the RMSE scores as well as having more accurate 12 week forecasts. Another determinant in the reduced accuracy of the forecast into 2014 is possibly due to the nature of the cattle market. As supplies tightened and fed slaughter prices were at record highs, feedlot operators were taking advantage of this and holding back cattle from entering the packing sector. Therefore slaughter numbers may have been influenced by market conditions for 2014. . Estimating the model into 2015 will provide validation of the PDL model and forecasting techniques. Overall, both forecasting procedures validated that the transformed weekly placement data determines the weekly slaughter numbers and provides the amount of time feeders will be in the feedlot.

The objectives of this study have been satisfied and provide contributions to prior research due to unique econometric analysis techniques. A main contribution of this research is a powerful econometric tool that can be used for cattle flow analysis for the feedlot and packing industry. The relationship between weekly placements is significant in determining the weekly fed cattle slaughter using various data transformation procedures. Model results provide the number of weeks on feed and gives insight for short-term fed cattle marketing decisions by the feedlot operator. This tool provides a fairly accurate forecast with three types of weekly transformed data. Results are robust in that each transformation can provide a sound forecast of slaughter numbers as well as total beef production. Overall, the results support that USDA monthly data has great value in predicting weekly slaughter numbers, especially when estimated seasonality is accounted for in the transformation. This research may provide a tool for industry and academic purposes in understanding the complexities surrounding the diverse beef production industry.

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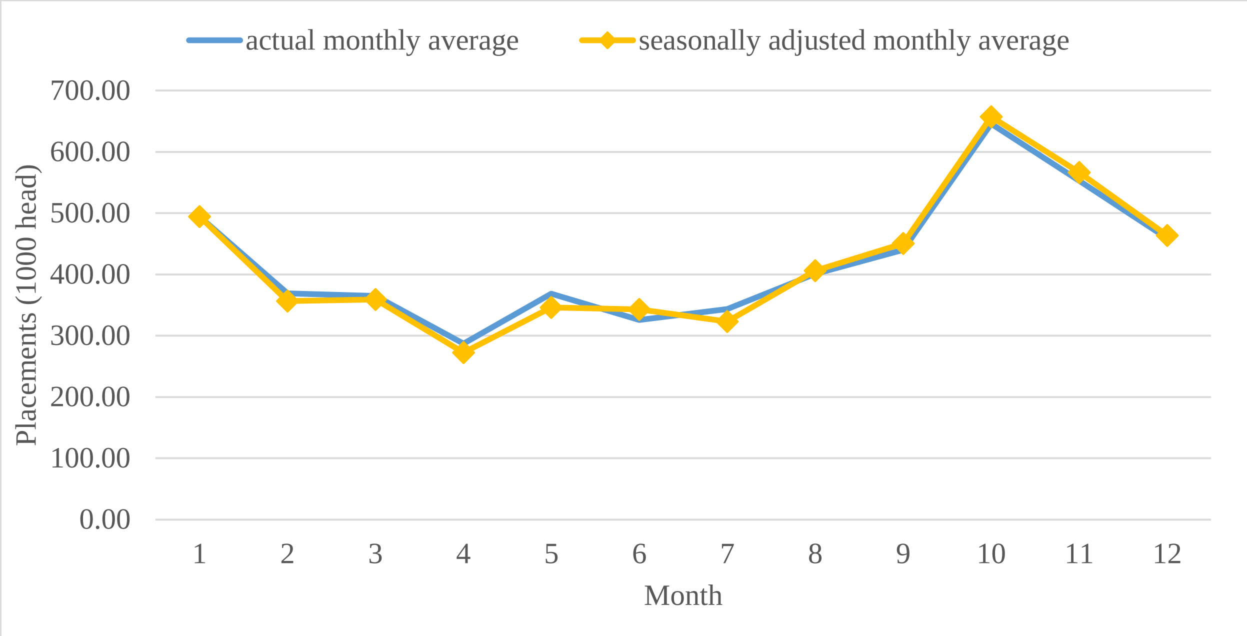
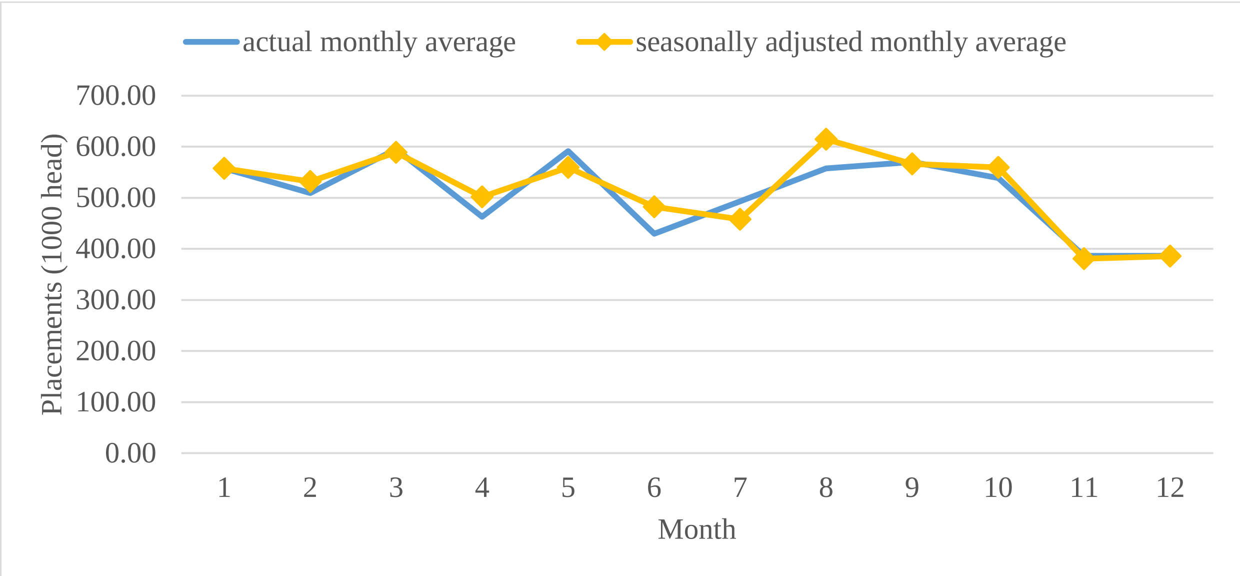
APPENDIX: A

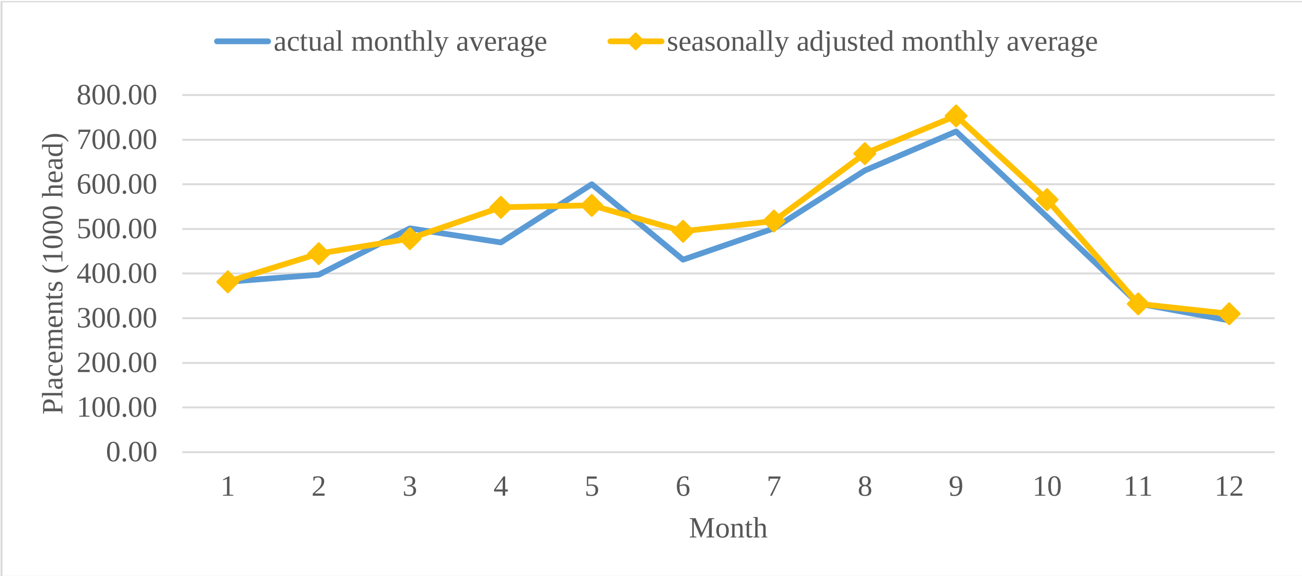
Appendix A (Figure 1): Seasonally Estimated Monthly Average Placements vs. Actual Monthly Average Placement for 600-699 lbs. Feeders




Appendix A (Figure 2): Seasonally Estimated Monthly Average Placements vs. Actual Monthly Average Placement for 700-799 lbs. Feeders



Appendix A (Figure 3): Seasonally Estimated Monthly Average Placements vs. Actual Monthly Average Placement for 800-899 lbs. Feeders



APPENDIX: B

Appendix B (Table 1): Estimate Results of Polynomial Distributed Lag Model using SAS "SP" data transformation

| **# of observations** | 993 | **Mean Square Error** | | 837.8546 | |
|---|---|---|---|---|---|
| **Mean of Dep. Variable** | 527.92761 | **R-Square** | | 0.6048 | |
| **Std. Dev. Of Dep. Var.** | 45.316762 | **Schwartz BIC** | | 8071.975 | |
| **Sum of Squared Errors** | 692067.869 | **Durbin-Watson** | | 1.3045 | |
| **Variables** | **Estimate** | **Standard Error** | **Variables** | **Estimate** | **Standard Error** |
| SP600(-25) | 0.004048*** | 0.000267 | SP699(-16) | 0.009345*** | 0.000848 |
| SP600(-26) | 0.007834*** | 0.000517 | SP699(-17) | 0.01784*** | 0.001618 |
| SP600(-27) | 0.011359*** | 0.00075 | SP699(-18) | 0.025486*** | 0.002311 |
| SP600(-28) | 0.014623*** | 0.000966 | SP699(-19) | 0.032282*** | 0.002928 |
| SP600(-29) | 0.017626*** | 0.001164 | SP699(-20) | 0.038228*** | 0.003467 |
| SP600(-30) | 0.020368*** | 0.001345 | SP699(-21) | 0.043326*** | 0.003929 |
| SP600(-31) | 0.022849*** | 0.001509 | SP699(-22) | 0.047573*** | 0.004315 |
| SP600(-32) | 0.025068*** | 0.001655 | SP699(-23) | 0.050971*** | 0.004623 |
| SP600(-33) | 0.027027*** | 0.001785 | SP699(-24) | 0.05352*** | 0.004854 |
| SP600(-34) | 0.028724*** | 0.001897 | SP699(-25) | 0.055219*** | 0.005008 |
| SP600(-35) | 0.03016*** | 0.001992 | SP699(-26) | 0.056068*** | 0.005085 |
| SP600(-36) | 0.031336*** | 0.002069 | SP699(-27) | 0.056068*** | 0.005085 |
| SP600(-37) | 0.032249*** | 0.00213 | SP699(-28) | 0.055219*** | 0.005008 |
| SP600(-38) | 0.032902*** | 0.002173 | SP699(-29) | 0.05352*** | 0.004854 |
| SP600(-39) | 0.033294*** | 0.002198 | SP699(-30) | 0.050971*** | 0.004623 |
| SP600(-40) | 0.033425*** | 0.002207 | SP699(-31) | 0.047573*** | 0.004315 |
| SP600(-41) | 0.033294*** | 0.002198 | SP699(-32) | 0.043326*** | 0.003929 |
| SP600(-42) | 0.032902*** | 0.002173 | SP699(-33) | 0.038228*** | 0.003467 |
| SP600(-43) | 0.032249*** | 0.00213 | SP699(-34) | 0.032282*** | 0.002928 |
| SP600(-44) | 0.031336*** | 0.002069 | SP699(-35) | 0.025486*** | 0.002311 |
| SP600(-45) | 0.03016*** | 0.001992 | SP699(-36) | 0.01784*** | 0.001618 |
| SP600(-46) | 0.028724*** | 0.001897 | SP699(-37) | 0.009345*** | 0.000848 |
| SP600(-47) | 0.027027*** | 0.001785 | | | |
| SP600(-48) | 0.025068*** | 0.001655 | | | |
| SP600(-49) | 0.022849*** | 0.001509 | | | |
| SP600(-50) | 0.020368*** | 0.001345 | | | |
| SP600(-51) | 0.017626*** | 0.001164 | | | |

| | | | | | |
|---|---|---|---|---|---|
| SP600(-52) | 0.014623*** | 0.000966 | | | |
| SP600(-53) | 0.011359*** | 0.00075 | | | |
| SP600(-54) | 0.007834*** | 0.000517 | | | |
| SP600(-55) | 0.004048*** | 0.000267 | | | |
| **Variables** | Estimate | Standard Error | Variables | Estimate | Standard Error |
| SP799(-12) | 0.013719*** | 0.000744 | SP800(-5) | 0.006674*** | 0.001086 |
| SP799(-13) | 0.026246*** | 0.001423 | SP800(-6) | 0.012606*** | 0.002052 |
| SP799(-14) | 0.037579*** | 0.002038 | SP800(-7) | 0.017797*** | 0.002897 |
| SP799(-15) | 0.04772*** | 0.002588 | SP800(-8) | 0.022246*** | 0.003622 |
| SP799(-16) | 0.056667*** | 0.003073 | SP800(-9) | 0.025954*** | 0.004225 |
| SP799(-17) | 0.064422*** | 0.003493 | SP800(-10) | 0.02892*** | 0.004708 |
| SP799(-18) | 0.070983*** | 0.003849 | SP800(-11) | 0.031145*** | 0.00507 |
| SP799(-19) | 0.076352*** | 0.00414 | SP800(-12) | 0.032628*** | 0.005312 |
| SP799(-20) | 0.080527*** | 0.004367 | SP800(-13) | 0.03337*** | 0.005432 |
| SP799(-21) | 0.083509*** | 0.004528 | SP800(-14) | 0.03337*** | 0.005432 |
| SP799(-22) | 0.085299*** | 0.004625 | SP800(-15) | 0.032628*** | 0.005312 |
| SP799(-23) | 0.085895*** | 0.004658 | SP800(-16) | 0.031145*** | 0.00507 |
| SP799(-24) | 0.085299*** | 0.004625 | SP800(-17) | 0.02892*** | 0.004708 |
| SP799(-25) | 0.083509*** | 0.004528 | SP800(-18) | 0.025954*** | 0.004225 |
| SP799(-26) | 0.080527*** | 0.004367 | SP800(-19) | 0.022246*** | 0.003622 |
| SP799(-27) | 0.076352*** | 0.00414 | SP800(-20) | 0.017797*** | 0.002897 |
| SP799(-28) | 0.070983*** | 0.003849 | SP800(-21) | 0.012606*** | 0.002052 |
| SP799(-29) | 0.064422*** | 0.003493 | SP800(-22) | 0.006674*** | 0.001086 |
| SP799(-30) | 0.056667*** | 0.003073 | | | |
| SP799(-31) | 0.04772*** | 0.002588 | | | |
| SP799(-32) | 0.037579*** | 0.002038 | | | |
| SP799(-33) | 0.026246*** | 0.001423 | | | |
| SP799(-34) | 0.013719*** | 0.000744 | | | |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | **Variables** | **Estimate** | **Standard Error** |
| lnratioslc(-1) | 0.355558 | 5.0164 | lnratioccs(-1) | 4.152153*** | 0.8474 |
| lnratioslc(-2) | -0.292325 | 3.2086 | lnratioccs(-2) | 2.779758*** | 0.572 |
| lnratioslc(-3) | -0.817096 | 1.7093 | lnratioccs(-3) | 1.606348*** | 0.3609 |
| lnratioslc(-4) | -1.218756 | 0.6852 | lnratioccs(-4) | 0.631924 | 0.2458 |
| lnratioslc(-5) | -1.497303 | 0.9057 | lnratioccs(-5) | -0.143516 | 0.2503 |
| lnratioslc(-6) | -1.652738 | 1.5213 | lnratioccs(-6) | -0.719969*** | 0.3067 |
| lnratioslc(-7) | -1.685062 | 1.9363 | lnratioccs(-7) | -1.097438*** | 0.3517 |
| lnratioslc(-8) | -1.594273 | 2.093 | lnratioccs(-8) | -1.275921*** | 0.364 |
| lnratioslc(-9) | -1.380373 | 1.9804 | lnratioccs(-9) | -1.255419*** | 0.3369 |
| lnratioslc(-10) | -1.04336 | 1.5948 | lnratioccs(-10) | -1.035931*** | 0.2679 |

| | | | | | |
|---|---|---|---|---|---|
| lnratioslc(-11) | -0.583236 | 0.9349 | lnratioccs(-11) | -0.617458*** | 0.1558 |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | | | |
| h1day | -37.8738*** | 3.4363 | | | |
| h2day | -91.8063*** | 7.246 | | | |

(Note: Single asterisks denote significance at the 10% level; double asterisks denote significance at the 5% level; triple asterisk denote significance at 1% level; no asterisks means not significant at all.)

Appendix B (Table 2): Estimate Results of Polynomial Distributed Lag Model using Fixed "WP" data transformation

| # of observations | 993 | Mean Square Error | 816.1777 |
|---|---|---|---|
| Mean of Dep. Variable | 527.928 | R-Square | 0.6136 |
| Std. Dev. Of Dep. Var. | 45.3168 | Schwartz BIC | 8116.925 |
| Sum of Squared Errors | 679876 | Durbin-Watson | 1.3443 |

| Variables | Estimate | Standard Error | Variables | Estimate | Standard Error |
|---|---|---|---|---|---|
| WP600(-25) | 0.004793*** | 0.000436 | WP699(-16) | 0.010209*** | 0.000866 |
| WP600(-26) | 0.009187*** | 0.000837 | WP699(-17) | 0.019489*** | 0.001653 |
| WP600(-27) | 0.013182*** | 0.0012 | WP699(-18) | 0.027842*** | 0.002361 |
| WP600(-28) | 0.016777*** | 0.001528 | WP699(-19) | 0.035266*** | 0.002991 |
| WP600(-29) | 0.019973*** | 0.001819 | WP699(-20) | 0.041762*** | 0.003542 |
| WP600(-30) | 0.022769*** | 0.002073 | WP699(-21) | 0.047331*** | 0.004014 |
| WP600(-31) | 0.025165*** | 0.002291 | WP699(-22) | 0.051971*** | 0.004408 |
| WP600(-32) | 0.027163*** | 0.002473 | WP699(-23) | 0.055683*** | 0.004722 |
| WP600(-33) | 0.02876*** | 0.002619 | WP699(-24) | 0.058467*** | 0.004958 |
| WP600(-34) | 0.029959*** | 0.002728 | WP699(-25) | 0.060323*** | 0.005116 |
| WP600(-35) | 0.030758*** | 0.002801 | WP699(-26) | 0.061251*** | 0.005195 |
| WP600(-36) | 0.031157*** | 0.002837 | WP699(-27) | 0.061251*** | 0.005195 |
| WP600(-37) | 0.031157*** | 0.002837 | WP699(-28) | 0.060323*** | 0.005116 |
| WP600(-38) | 0.030758*** | 0.002801 | WP699(-29) | 0.058467*** | 0.004958 |
| WP600(-39) | 0.029959*** | 0.002728 | WP699(-30) | 0.055683*** | 0.004722 |
| WP600(-40) | 0.02876*** | 0.002619 | WP699(-31) | 0.051971*** | 0.004408 |
| WP600(-41) | 0.027163*** | 0.002473 | WP699(-32) | 0.047331*** | 0.004014 |
| WP600(-42) | 0.025165*** | 0.002291 | WP699(-33) | 0.041762*** | 0.003542 |
| WP600(-43) | 0.022769*** | 0.002073 | WP699(-34) | 0.035266*** | 0.002991 |
| WP600(-44) | 0.019973*** | 0.001819 | WP699(-35) | 0.027842*** | 0.002361 |
| WP600(-45) | 0.016777*** | 0.001528 | WP699(-36) | 0.019489*** | 0.001653 |
| WP600(-46) | 0.013182*** | 0.0012 | WP699(-37) | 0.010209*** | 0.000866 |
| WP600(-47) | 0.009187*** | 0.000837 | | | |
| WP600(-48) | 0.004793*** | 0.000436 | | | |

| Variables | Estimate | Standard Error | Variables | Estimate | Standard Error |
|---|---|---|---|---|---|
| WP799(-12) | 0.014716*** | 0.000876 | WP800(-5) | 0.008801*** | 0.00131 |
| WP799(-13) | 0.028031*** | 0.001669 | WP800(-6) | 0.016428*** | 0.002445 |
| WP799(-14) | 0.039944*** | 0.002379 | WP800(-7) | 0.022881*** | 0.003405 |

| | | | | | |
|---|---|---|---|---|---|
| WP799(-15) | 0.050455*** | 0.003005 | WP800(-8) | 0.028162*** | 0.004191 |
| WP799(-16) | 0.059565*** | 0.003547 | WP800(-9) | 0.032269*** | 0.004802 |
| WP799(-17) | 0.067274*** | 0.004006 | WP800(-10) | 0.035202*** | 0.005239 |
| WP799(-18) | 0.073581*** | 0.004382 | WP800(-11) | 0.036962*** | 0.005501 |
| WP799(-19) | 0.078486*** | 0.004674 | WP800(-12) | 0.037549*** | 0.005588 |
| WP799(-20) | 0.08199*** | 0.004883 | WP800(-13) | 0.036962*** | 0.005501 |
| WP799(-21) | 0.084092*** | 0.005008 | WP800(-14) | 0.035202*** | 0.005239 |
| WP799(-22) | 0.084793*** | 0.00505 | WP800(-15) | 0.032269*** | 0.004802 |
| WP799(-23) | 0.084092*** | 0.005008 | WP800(-16) | 0.028162*** | 0.004191 |
| WP799(-24) | 0.08199*** | 0.004883 | WP800(-17) | 0.022881*** | 0.003405 |
| WP799(-25) | 0.078486*** | 0.004674 | WP800(-18) | 0.016428*** | 0.002445 |
| WP799(-26) | 0.073581*** | 0.004382 | WP800(-19) | 0.008801*** | 0.00131 |
| WP799(-27) | 0.067274*** | 0.004006 | | | |
| WP799(-28) | 0.059565*** | 0.003547 | | | |
| WP799(-29) | 0.050455*** | 0.003005 | | | |
| WP799(-30) | 0.039944*** | 0.002379 | | | |
| WP799(-31) | 0.028031*** | 0.001669 | | | |
| WP799(-32) | 0.014716*** | 0.000876 | | | |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | **Variables** | **Estimate** | **Standard Error** |
| lnratioslc(-1) | -2.336618 | 4.8688 | lnratioccs(-1) | 4.200841*** | 0.8375 |
| lnratioslc(-2) | -2.091425 | 3.1196 | lnratioccs(-2) | 2.894203*** | 0.5639 |
| lnratioslc(-3) | -1.852787 | 1.6702 | lnratioccs(-3) | 1.772514*** | 0.3549 |
| lnratioslc(-4) | -1.620704 | 0.682 | lnratioccs(-4) | 0.835773*** | 0.2429 |
| lnratioslc(-5) | -1.395175 | 0.8799 | lnratioccs(-5) | 0.083981 | 0.2504 |
| lnratioslc(-6) | -1.1762 | 1.4702 | lnratioccs(-6) | -0.482863** | 0.3077 |
| lnratioslc(-7) | -0.963781 | 1.8707 | lnratioccs(-7) | -0.864757*** | 0.3525 |
| lnratioslc(-8) | -0.757915 | 2.0224 | lnratioccs(-8) | -1.061703*** | 0.3645 |
| lnratioslc(-9) | -0.558605 | 1.9139 | lnratioccs(-9) | -1.0737*** | 0.3371 |
| lnratioslc(-10) | -0.365849 | 1.5415 | lnratioccs(-10) | -0.900749*** | 0.2679 |
| lnratioslc(-11) | -0.179647 | 0.9038 | lnratioccs(-11) | -0.542849*** | 0.1557 |
| | | | | | |
| **Variables** | **Estimate** | **Standard Error** | | | |
| h1day | -40.21*** | 3.4022 | | | |
| h2day | -92.8051*** | 7.1557 | | | |

(Note: Single asterisks denote significance at the 10% level; double asterisks denote significance at the 5% level; triple asterisk denote significance at 1% level; no asterisks means not significant at all.)