Forecasting Weekly Beef Production using Monthly Feedlot Placements of Steers and Heifers

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A Thesis Submitted to the Faculty of the

AGRICULTURAL AND RESOURCE ECONOMICS DEPARTMENT

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

2008

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ACKNOWLEDGEMENTS

This thesis could not have been possible without the support of the Agricultural and Resource Economics Department, the direct or indirect contribution of many people, and I would like to acknowledge each and every one of them.

I express my deepest gratitude to Dr. Russell Tronstad for his financial support, intellectual encouragement, constructive criticism, and willingness to help me whenever I needed it. I express my sincere appreciation for Dr. Satheesh Aradhyula for his help with the model codes. I express my heartfelt thanks to Dr. Roger Dahlgran for his understanding and constant support. I am extremely thankful to Dr. Gary D. Thompson for his training in project. I thank Nancy Smith for helping with the formatting of the thesis, and helping me whenever I needed an advice in my student life.

Finally, I would like to thank my family for their unwavering support and encouragement in my pursuit of graduate studies. I would thank my friend, Soni Yatheendradas, for his great effort in helping me. I would also thank my friend Sonam Gupta for her advice. I would also thank my friends in the department and outside for the enriching experiences that are integral parts of this student life.

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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, cost of gain, quality premiums, seasonality, and other factors are used to quantify relationships between feeder placements, slaughter numbers and average slaughter weights. Furthermore, a comparison of the forecasting accuracy of alternative seasonal adjustment approaches is carried out in this thesis to evaluate how to best capture seasonal phenomena. This study will improve understanding of the appropriate lag lengths and weight gain relationships between feedlot placements, economic incentives of cattle feeding, and federally inspected fed cattle marketings.

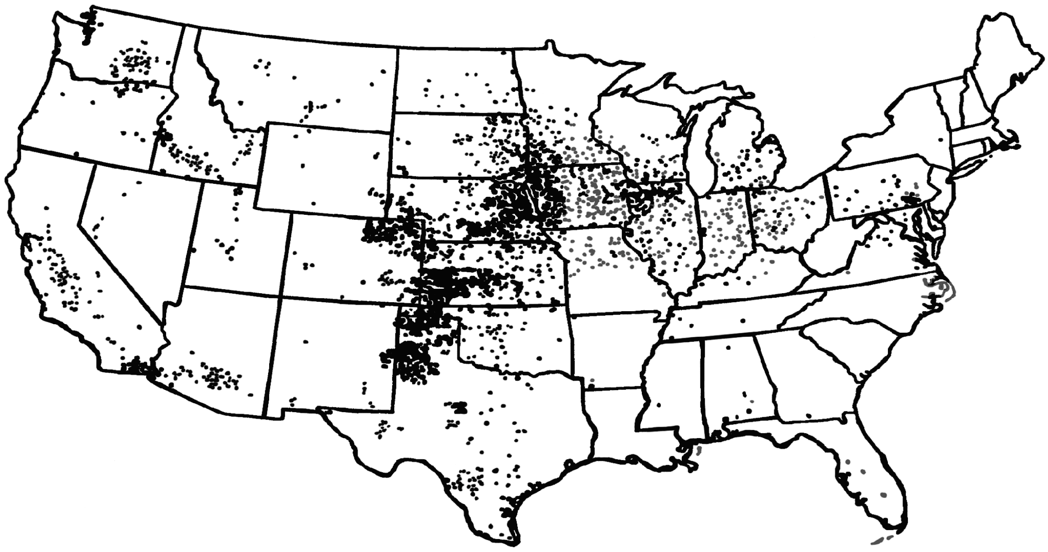
Key Words: choice-select price spread, polynomial distributed lag, seasonality

CHAPTER 1: INTRODUCTION

1.1 Cattle supply chain background information

The United States is the leading beef producer in the world, Almost 26.9 billion pounds of beef were produced in the United States in 2000 and per capita consumption totaled 78 pounds (Beef Cow-calf Production, 2000). Thus, beef production is an important industry for the U.S. The beef industry is composed of seedstock, cow-calf, stocker, feedlot, and packer sectors and these sectors are concentrated in different regions. The feedlot sector is concentrated in Texas, Oklahoma, Kansas, Colorado, Nebraska and Iowa, with thousands of feeder steers and heifers placed into feedlots in these states every month. Cattle feeding activities have a significant economic impact in many rural counties located in these states. The beef processing or packing industry for beef is concentrated in the states mentioned above as well. The concentration in these regions has been increasing. For example, the four largest meat packers accounted for 26% of the fed cattle slaughtered in 1972 and 87% by 1994 (Packers and Stockyards Administration. Statistical Report, U.S. Dept. of Ag., Washington, D.C. 1992.)

Figure 1.1: Locations of cattle feedlots in U.S.A.



(Source: John C. McKissick & Dan T. Brown, “Profitable Cattle Marketing for the Cow-Calf Producer”.)

There are a few stages in the life of a steer or heifer. The first stage, or the cow-calf sector, is from birth to weaning. At weaning, calves generally weigh at least 300 to 400 pounds. The lighter calves will usually be moved to some type of a forage-based stocker program, where another 300 to 400 pounds will be added. The daily weight gain during these stages depends on the frame of each animal. As shown in table 1.1 (Backgrounding - Feeder Cattle Nutrition, 2008), large-frame calves grow faster, and as such, have greater daily dry matter intakes than small- and medium-frame calves. They are also fattened and slaughtered at heavier weights. For large-frame stocker steers and heifers, the daily average weight gain is from 2.0 to 2.5

pounds, while the gain for small and medium frames is approximately 1.5 to 2.0 pounds per day. As stockers grow to a weight of 600 to 800 pounds, they will typically be moved into feedlots. It may take up to eleven months after weaning for some calves to gain enough weight to be moved into feedlots. Even if the target weight is at the upper range of 875 lbs., large frame steers and heifer will likely reach this weight in less than six months after weaning. Some heavier large frame calves are placed directly into feedlots without being in a forage-based stock program if they weight around 600 lbs after weaning. And in the feedlot, average daily weight gains are generally at least three pounds per day.

In the U.S., most feeder cattle are from domestic markets and only around 10% are imported from Mexico and Canada. In recent decades, Mexico is the main country that supplies feeder cattle to the U.S., but during the last two years, feeder imports from Canada have played a more substantial role.

Table1.1: Target sale weight

	Small Frame	Medium Frame	Large Frame
Purchase Weight	300 - 400 lb.	400 - 500 lb.	500 - 600 lb.
Backgrounding Gain (lb. per day)			
Steers and Heifers	1.50 - 1.75 lb.	1.50 - 2.00 lb.	
Steers			2.25 - 2.70 lb.
Heifers			2.00 - 2.50 lb.
Target Feeder Weight and Destination			
To grass	650 - 700 lb.		
To feedlot	800 - 850 lb.		
Steers and Heifers to feedlot		825 - 875 lb.	825 - 875 lb.
Expected Slaughter Weight			
Steers	1100 lb. +	1150 - 1300 lb. +	1300 - 1525 lb.
Heifers	900 lb. +	950 - 1050 lb. +	1100 - 1200 lb. +

(Source: Backgrounding - Feeder Cattle Nutrition, 2008)

1.1.1 Importance of issue

In this study, two markets or stages in the supply chain are focused on 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 cattle feeders, steers and heifers placed in their feedlots are an investment, and their return is realized when the feeder cattle reaches a heavy enough weight to be sold in the slaughter market. On the other hand, beef packers' inventories are also those steers and heifers on feed getting ready for slaughter. Greater feedlots placement will eventually lead to greater slaughter numbers, but the slaughter rate depends on a number of production and market factors. In addition, different placement weights result in different days on feed at the feedlot. The time on feed is also an important factor for cattle feeders and beef product producers. Thus, quantifying how animals are placed at different weights and brought to slaughter for different seasons and market conditions, is important information for the cattle sector. This means that providing qualitative and quantitative information and forecasts regarding placements and their corresponding slaughter markets can help feeders improve their price bids for placements and adjustments to feeding activities.

In December 1995, the USDA began collecting and publishing monthly data on the number of steers and heifers placed in feedlots by the four weight categories of less than 600 lbs., 600 to 699 lbs., 700 to 799 lbs., and more than 800 lbs respectively. During the last decade, several studies have been done on the relationship between the monetary gain of cattle feeders and the cost of gain. However, no known formal studies have quantified the relationship between monthly placements and weekly federally inspected slaughter numbers. In part, this is because the data series began only in December 1995. In addition, the frequency of placement data is monthly while slaughter data is weekly. A contribution of this study is distributing monthly placements to weeks while preserving the estimated seasonality pattern using the

Solver function in Excel™.

1.1.2 Procedures regarding placement steers and heifers

As noted earlier, placement data of feeders released by the USDA are separated into four placement weight classes: less than 600 lbs., 600 to 699 lbs., 700 to 799 lbs., and 800 lbs. or more. The slaughter weight for steers typically averages between 1200 and 1400 lbs. Slaughter weights for heifers are somewhat less than steers, ranging from 1100 to 1300 lbs. Since USDA's placement data does not distinguish between steers and heifers, we are unable to test the relationship between placement and slaughter separately for steers or heifers. Different classes of placement weights lead to different days (or weeks) of being fed in the feedlot. That is, lighter feeders will be kept on feed for a longer time to reach their slaughter weight (i.e. for the class of weight that is less than 600 lbs, the steers and heifers have to gain at least 600 lbs). Suppose the average daily weight gain is around 3 pounds, then for these lighter feeders, it will take at least 7 to 8 months in the feedlot before they will reach a minimum slaughter weight. However, for the heavier placements, a shorter time span is needed for them to reach their slaughter weight (i.e. for the class with weights greater than 800 lbs, the weight gain may be less than 400 lbs). Thus, steers and heifers placed at heavier weights gain fewer total pounds while on feed than those paced at lighter weights. These placement-weight data are expected to improve fed cattle marketing projections. This is because cattle placed on feed at a particular weight (the same weight category) will typically be fed for a similar number of days before slaughter so that their slaughter times match those of the marketing projections.

1.1.3 Overview of feeder placements into feedlots and slaughter numbers

In order to keep their feedlots relatively full, cattle feeders feeding activities and replacements for the four different weight classes of placements have a similar pattern for the 12 years considered. Figure 1.2 shows the number of U.S. monthly placements (in thousands) for steers and heifers of lightest weight class (less than 600 lbs.) and heaviest weight class (greater than 800 lbs.) from December 1995 to December 2007 in the U.S. It shows the quantity of placements and how they are distributed through the years. Sometimes the monthly placement number is as low as 200 thousand head, and sometimes it is more than 1 million head. And this pattern changes regularly for each year and for each class, as seen in Figure 1.2, Placement numbers have great variation throughout the calendar year (i.e., intra-annual variation). High placements usually are double in size of the lowest and sometimes even more: these high values usually occur towards the end of the year, with the valleys following them and in the 1st quarter of the next year. In comparison, slaughter numbers do not present as much variance between their peaks and valleys, although they do fluctuate from year-to-year and within each year. Figure 1.3 represents weekly slaughter numbers (in thousands) from December 1995 to December 2007: the slaughter number is mainly distributed between 500 and 600 thousand head, while there is a very significant drop at the end of each year. The annually recurring change in both of the figures indicates that there is a seasonal pattern in feedlots placement that carries over to the slaughter market. Thus, special consideration is given to quantifying the seasonal effects. Otherwise, estimates would undoubtedly be biased. Because seasonal fluctuations in the data make it difficult to analyse whether changes for a given period reflect important increases or decreases in the level of the data, or are due to regularly occurring variation, seasonal influences and adjustments are illustrated in detail in Chapter 2.

Figure 1.2: Monthly placement of steers and heifers (in 1000 Heads) for weight classes of less than 600lbs and greater than 800 lbs.

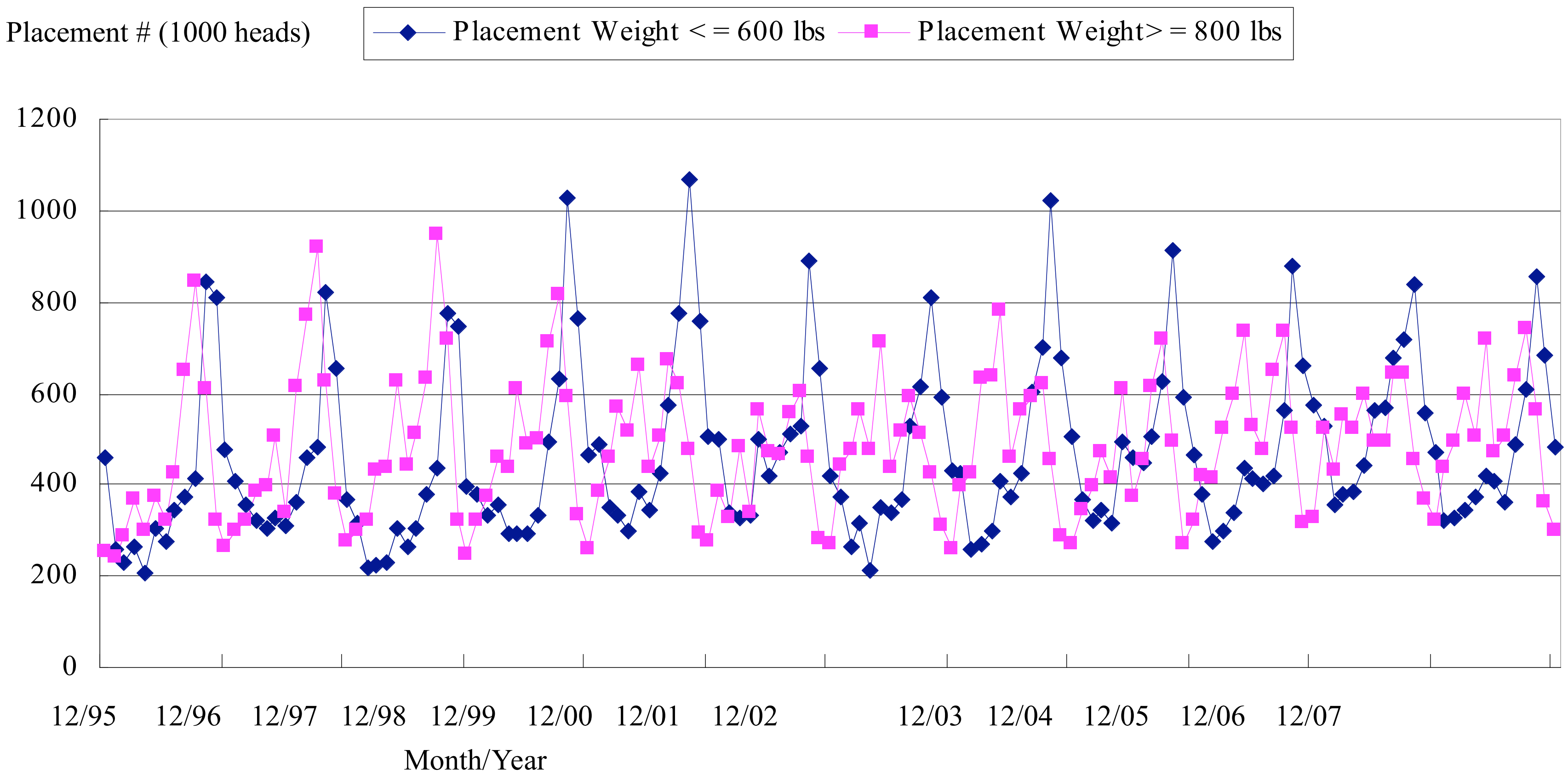
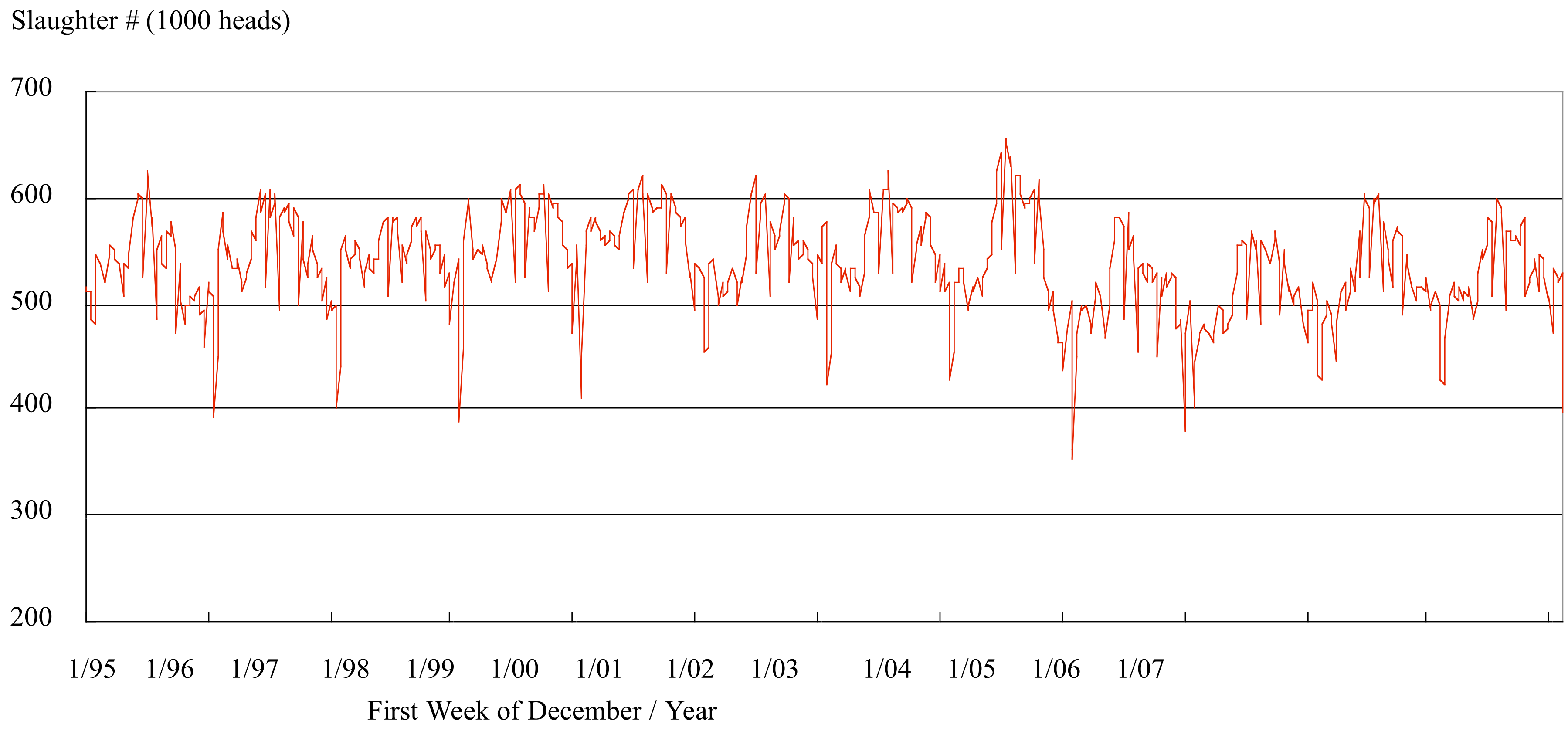


Figure 1.3: Total weekly slaughter numbers from December 1995 to the end of 2007 (1000 heads)



1.2 Scope and objectives

In answering the needs of the market to provide more qualified information, this study will fulfill the following objectives:

1. Formally estimate the lag relationships between placement and slaughter numbers using an empirical model, quantifying the time period for feedlot steers and heifers to attain the slaughterhouse for different weight classes.
2. Quantify and test for seasonal effects in the relationship between placements and slaughter numbers.
3. Quantify market factors like cost of gain, quality premiums, and other related variables on slaughter numbers and slaughter weights.
4. Research the relationships of slaughter weights with the cost of gain and seasonality to find out which variables most influence beef production.

1.3 Literature review

In this section, literature related to beef production and cattle placements will be reviewed. Previous studies are reasonable but not accurate because they do not incorporate U.S. feedlot placement data. This thesis will analyze these markets in detail and quantify the connection between placements and production.

1.3.1 Fed cattle marketings and feeder cattle placements

Since USDA started collecting monthly feedlot placement data for these different weight classes, some studies have been made on this topic. One such study is by Norwood and Schroeder (2000). They tested the usefulness of weight-classified placement data in forecasting fed cattle marketing and fed cattle price, by comparing it with the empirical model using aggregate monthly data. Their study shows that the model using weight-classified placement data improves marketing forecasts a little, but contributed nothing to price forecasts. In their research, they used private feeder-cattle placement-weight data collected by Cattle Fax and by Professional Cattle Consultants (PCC). This is because the USDA data were only available for a few years, and the series was not sufficient to derive and test statistical relationships. The private monthly placement data collected by Cattle Fax and PCC represent approximately 20% to 25% of U.S. placements, divided into four class weights of 600 lbs., 600 to 699 lbs., 700 to 799 lbs., and over 800 lbs. respectively, from 1985 to 1997. The private data may not be as accurate as the USDA data, since the private data represents a smaller sample of placements for the U.S.

Another study on forecasting short-run fed cattle slaughter marketing forecasting was done by Bacon, Trapp and Koontz (1992). In their study, they used cattle on feed data from seven states, including Arizona, California, Colorado, Iowa, Kansas, Nebraska and Texas. They estimated the previous month's feedlot placements and the current month's beginning inventory of cattle on feed. Hence, the data are limited in explaining the flow of cattle through the feedlot cycle. In their model of forecasting monthly fed cattle marketings by using USDA aggregate time series data of cattle on feed, they explain marketing numbers as a function of the seven-state cattle-on-feed reported four to seven months earlier with the consideration of seasonal factors and time trend. They argued that cattle on feed four to six months before slaughter explains a large portion of the marketing numbers at a rate of 0.43. This total multiplier on the lag-distributed placement suggests that a 1,000 head increase (decrease) in placement results in a 430 head increase (decrease) in market seven months later. For one-month ahead slaughter forecasts for the 1991 calendar year, their results based on 1986 to 1990 data yielded a RMSE of 4.6% for actual slaughter marketing. Their choice of prior four to seven months cattle on feed depends upon the biological rates of gain for feeder cattle. But different weights of feeder animals are placed or fed at different times in the year and different feeding programs are followed – especially if market incentives change. The placement of four to seven months early is a general range for different placement weights and this may not be a proper conclusion for lighter or heavier placements. In addition, the monthly placement data used in this model is tracked out from the number of aggregate monthly cattle on feed, which result in a bias in the data used for the model. The RMSE turns out comparatively small because the forecasting period is monthly for one calendar year, due to a small sample size. Previous studies have tried to forecast fed cattle marketing by using placement data. But because of the shortage of weight-classified placement data, those studies give general information; hence more work needs to be done for providing qualified information about how the fed cattle slaughter market works.

1.3.2 Studies related to cost of gain in the fed cattle market

Price plays a critical role in the supply-demand cycle. This also applies to the fed cattle slaughter market. Some studies have tried to figure out how cost of gain affects the cattle market. Marsh (1994) estimated monthly fed beef supply based on a dynamic model of fed cattle marketing and feeder cattle placements. He found out that fed cattle marketing are a first-order difference equation with a one-period lag on slaughter price and two-period lag on feeder and corn prices, while feeder placements are a first-order difference equation with one-period lags on slaughter and feeder prices and with no lags on corn price. Corn price is essential to anticipate the cost of gain. Though this cost of gain includes feeding-related expenses such as yardage fees, veterinary charges, and interest, by far, its largest component is the cost of feed, which is typically corn. Placement weight and slaughter weights will be adjusted in response to corn price changes (Anderson and Trapp, 2000). When corn prices go up so that feeding is less profitable, cattle feeders adjust to slaughter at lighter weights. On the other hand, as an indicator of return for cattle feeders, the prices of fed cattle and the choice-select spread are also expected to impact when animals are slaughtered. The choice-to-select price spread measures the price premium for quality, in the form of beef with more marbling. This is an important determinant of returns for beef production. The difference between choice and select prices is the result of supply and demand conditions in two different market segments – the choice versus the select market. These markets differ in the sense that choice beef has more marbling or intramuscular fat that produces desirable tenderness, juice, and taste attributes for most consumers. Because the percentage of feeders that grade choice is related to genetics, age, and time on feed, the price premium for choice over select beef will impact the timing of cattle on feed going to slaughter.

CHAPTER 2: DATA AND SEASONALITY

2.1 Data

The USDA placement and slaughter data described in the previous chapter was obtained from the Livestock Marketing Information Center (LMIC). The data includes monthly placements of feeders into feedlots and weekly federally inspected slaughter numbers of steers and heifers, cost of gain, price premiums, and other prices from December 1995 to December 2007. As mentioned before, cattle feedlots are concentrated in the four states of Colorado, Kansas, Nebraska and Texas. Table 2.1 shows the average monthly feedlot placements in those states with four weight classes. The data show that feedlot placements from all other states (5^{th} row in table 2.1) in each weight class do not exceed the placements for some of the four major states. According to the LMIC, total federally inspected slaughter numbers are generally comprised of about 50% to 60% steers, 25% to 30% heifers, and of 10% to 25% cows. The main purpose of this study is to use feedlot placements of steers and heifers by weight class to estimate future fed slaughter numbers. Thus, only steer and heifer slaughter numbers are utilized in this study. The estimation is done using data from Dec. 1995 to Dec. 2005, while the last 2 years of data from Jan. 2006 to Dec.

2007 are used for forecasting/validation to check out of sample model accuracy.

Table 2.1: Average monthly feedlots placements from the four leading states and other states (from December 1995 to December 2007 in 1000s)

	less 600 lbs	600-699 lbs	700-799 lbs	800 lbs plus
Colorado	33	44	66	59
Kansas	85	118	151	104
Nebraska	67	87	113	130
Texas	146	149	144	66
Other States	136	78	97	123

2.2 Seasonality and seasonal adjustment on placement data

Seasonality can be defined as a cyclical pattern which repeats at regular intervals within an annual time period. The effects of seasonal noise on regression estimates are considered as a form of systematic error in the analysis. Thus, seasonality needs to be accounted for to reflect accurate economic changes in the variables analyzed.

Seasonality is considered in most time series analysis, and in this study, is also very evident in the feeder placement and slaughter data (see Figures 1.2 and 1.3 in chapter one). Placement numbers of feeders into feedlots increase and decrease around the same time every year. This annual recurrence trend is examined in Figure

2.1, which displays average monthly placement values for each weight class over a 12-year horizon (from Dec. 1995 to Dec. 2007). For each class, placements climb up a little in March and May, and fall back down to a low level in April and June. After that, they start increasing from July and peak either in September as seen for the heavier two classes, 700 to 799 lbs. and greater than 800 lbs., or in October as seen for other two classes, less than 600 lbs. and 600 to 699 lbs., before dropping sharply towards the end of the year. In comparison with dramatic seasonal changes in placements, average weekly slaughter numbers for the same period in Figure 2.2 show that slaughter numbers are quite smoothly distributed over the year, staying between 500 to 600 thousand head, except for a few drops in the weeks 22, 27, 36, 48, and those at the end and beginning of the year. These decreases are due to holiday effects, i.e., those weeks are considered to be national holidays like Labor Day, Independence Day, Thanksgiving, Christmas and New Year. Dummy variables will be used later in the empirical model to capture the holiday effects on slaughter marketing. On the other hand, feedlots placements show strong seasonality in comparison with the slaughter market. The reason for this is that cow-calf operations are very seasonal in nature with most operations calving during the spring months to take advantage of forage availability. Seasonal weather factors also affect the growth of cattle, in contrast with the consumption of beef, which is more constant across time although peaks some with the “summer grilling season.” Part of the challenge of this analysis is quantifying the input of feedlot placements, which is highly seasonal, to the output of fed cattle marketings or consumption which is fairly constant. Hence, seasonal estimates of monthly feedlot placement data will be utilized in developing weekly placement data that will be linked to quantify weekly slaughter estimates.

Figure 2.2: Seasonal index (i.e., inter-annual average) of feedlot placements, Dec. 1995 – Dec. 2007

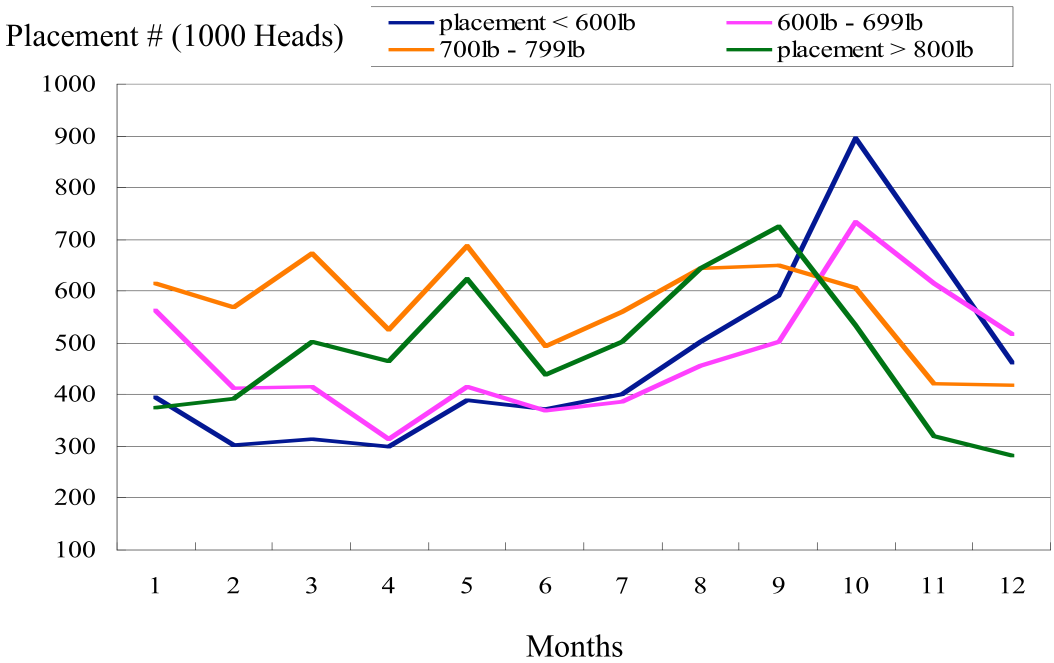
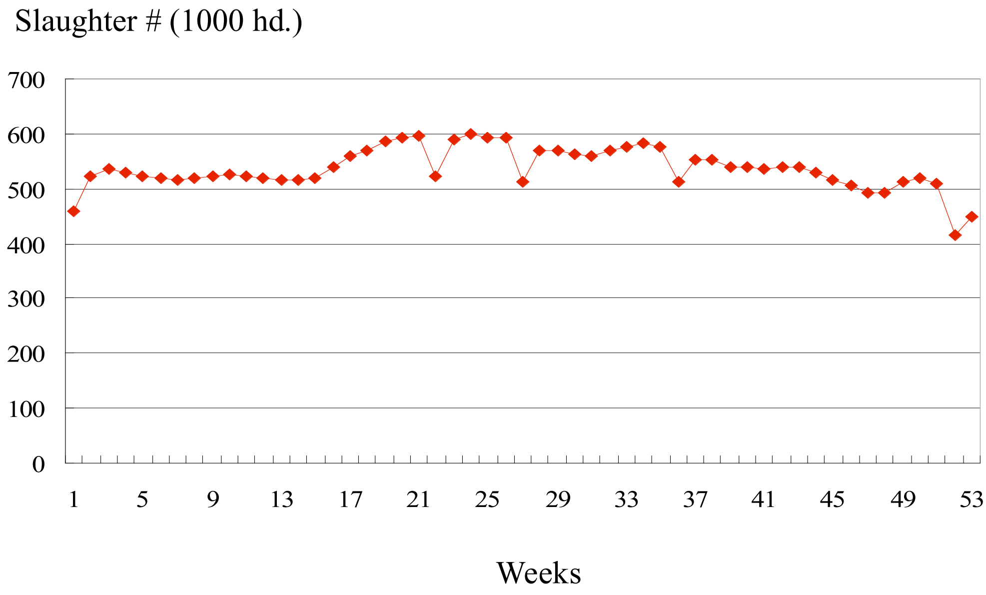


Figure 2.3: Average weekly slaughter numbers, Dec. 1995 to Dec. 2007



2.2.1 Factors influencing seasonality in placements

Several factors relate to seasonality in feedlot placements. These include climate, forage, and related economic considerations. Mark and Schroeder (1999) illustrate that optimal cattle feeding performance generally occurs with ambient temperatures between 40 and 60 degrees Fahrenheit. When temperatures are colder, the energy spent on body temperature maintenance increases, and when it is very hot, feed consumption declines, thus, there is less weight gain in both situations. Humidity is also an element that can influence the rate of weight gain. High humidity levels can increase heat stress levels on feedlot cattle. The results of Markand & Schroeder

(1999) also indicate that lightweight placements are more sensitive to temperature change than heavier weight calves. Besides the above climatic changes during the year, another reason arises from an economic viewpoint. In the fall (i.e., harvest) season, there is a new crop of corn, hay and other feedstuffs in the market. The above factors of natural and economic influence are regarded as the daily weight gain – cost of weight gain effects on cattle feeders, which contribute to the large increase in feedlot placement during the fall. Especially for the two lightweight classes, since they are most likely just weaned from the cow and their daily weight gain is influenced by the natural environment more than that of heavier groups. In addition, cattle feeders also have to consider the biological rates of gain for steers and heifers, and maintain a relative balanced distributed between the different age groups in the feedlots. For the two heavier classes, placements increase significantly in March and May. These animals were likely weaned in the fall and went into a stocker operation where they are then ready to be placed in the feedlot in the spring. Since they are placed at a heavier weight, they grow faster than the lighter class cattle. This lag between heavier and lighter classes is due to the different rates of biological growth among the four weight classes of the replacement cycle of steers and heifers in the feedlot.

2.2.2 Model used for estimating seasonality

Since the monthly feedlot placement data shows strong seasonality, seasonality is considered foremost in translating monthly placement numbers into weekly placements. The seasonal adjustment, which eliminates the influences of systematic events like weather, biological lags, and other recurring seasonal events from an economic time series, permits easier observation and analysis of other non-seasonal movements in the data. Aradhyula & Tronstad (2006) argue for the use of a "static" framework to estimate seasonality in the conditional means, variances and co-variances. They advocate that seasonality should be structured as 'static' rather than 'dynamic' so that random shocks are purged from known estimated seasonality components and seasonal effects should not have an infinite memory. The 'static' method was used in this study to estimate seasonality of monthly placement number for steers and heifers. The seasonality of feedlot placements (S) in this study is estimated as:

$$(1 - L)(Q_t - S_t^q) = \varepsilon_t, \qquad (2.1)$$

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

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

In the above equations, Q_t is the quantity of feedlot placements for in month t, L is the lag operator, S_t^q is seasonality of feedlot placements, and ε_t is the error term. The term m_t is simply month of the year divided by 12 (or a time index that cycles between 0 and 1), a_j are unknown parameters, and q is the order of the polynomial which needs to be determined for each weight category of feedlot placements. Seasonal parameters must satisfy the condition that seasonality is equal at the beginning and end of the year, i.e.,

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

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

$$S_t^q{}'(0) = S_t^q{}'(1) \quad or \quad \sum_{j=2}^{q} ja_j = 0\,\cdot \qquad (2.2b)$$

Seasonality estimated in equation (2.1), along with monthly lagged feedlot placements, will then be used to generate weekly feedlot placements. This process will be followed for all four reported weight classes. The following equations are detailed descriptions for the terms in equation (2.1). From equation (2.1), the following equation (2.3) is derived as:

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

Substituting equation (2.2) into (2.3) yields,

$$Q_t = Q_{t-1} + a_1\,(m_t - m_{t-1}) + a_2\,(m_t\text{-}m_{t-1})^2 + \ldots a_q(m_t\text{-}m_{t-1})^q + \varepsilon_t, \qquad (2.4)$$

Where $\sum_{j=1}^{q} a_j = 0$, *and* $\sum_{j=2}^{q} j a_j = 0.$

From equation (2.4), a nonlinear model relationship between the quantity of monthly placement Q and the time indicators m, for an appropriate polynomial order "q" and the parameters "a_q" will be estimated.

2.2.3 Schwarz Criteria and the seasonal adjusted pattern

The appropriate polynomial order "q" in the above seasonality model was determined using the Schwarz Criteria. The Schwarz Criteria is also named BIC (Bayesian Information Criteria), and a lower BIC value is preferred. The formula for the BIC is:

BIC = -2*lnL + k*ln(n),

where n is the number of observations, k is the number of parameters to be estimated, and L is the maximum value of the likelihood function for the estimated model. When the model error is normally distributed,

BIC = n*ln(SSE/n) + k*ln(n),

where SSE is the sum of the square errors. The BIC is an increasing function of both SSE and k. Under the situation of the same k, a lower BIC means a lower SSE and a better estimate of the model. Table 2.1 gives the Schwartz criteria values, and based on them, the appropriate polynomial orders for each weight class are decided, and the corresponding "a" parameters are derived. For placements in the weight class of less than 600 lbs., the polynomial order is 10, and for the weight classes of 600 to 699 lbs. and greater than 800 lbs., the polynomial order is 9, while for the placement weight class of 700 to 799 lbs., an order of 7 is best under the BIC criteria (the best values are highlighted in red). After obtaining the seasonality terms for each class of placement, the seasonality terms are placed back into the equation (2.1). Then, the seasonal adjusted monthly placements $\hat{Q}_t$ can be derived as

$$\hat{Q}_t = Q_{t-1} + (S_t - S_{t-1}) \qquad (2.5)$$

Some argue that seasonality can also be formulated by using a dummy variable for each month, (i.e. if it is Jan, then Jan is one and the other months are zero, and so for other months). If dummy variables are used, there are just 12 coefficients ("a"), one for each of the 12 months in a year. However, this does not provide a smooth pattern for transforming monthly feeder placements to weekly feeder placements. But by using a polynomial function, a smooth and continuous seasonality pattern throughout the year is obtained.

Table 2.2: Schwartz Criteria Values used to determine the appropriate polynomial order for seasonality.

Order	Placement < 600 lbs	600 – 699 lbs	700 – 799 lbs	Placement>= 800lbs
5	902.18	888.40	918.67	913.96
6	896.55	888.36	909.10	898.85
7	881.28	878.20	902.51	889.54
8	867.40	865.96	904.98	886.25
9	854.16	855.88	907.27	879.89
10	853.06	858.24	909.15	881.99

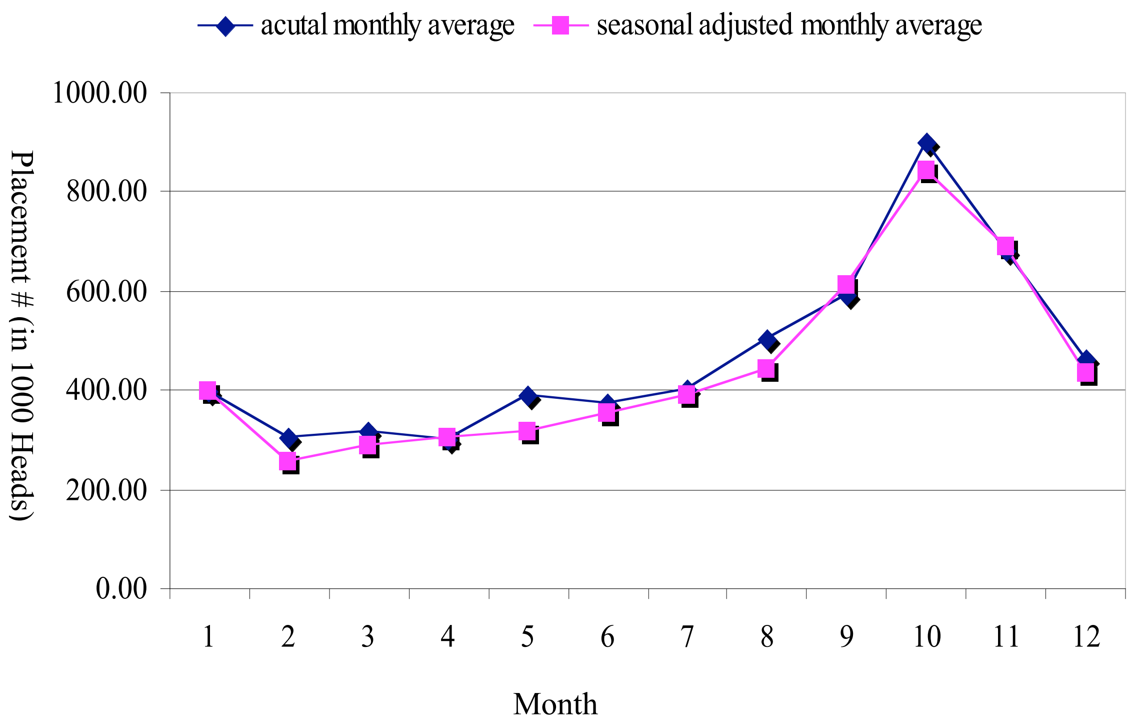
Table 2. 3: Estimated "A" values in seasonality function

Parameter	Less than 600 lbs	Standard Error	600 to 699 lbs	Standard Error	700 to 799 lbs	Standard Error	greater 800 lb	Standard Error
A1	11295	-	10340	-	5222	-	-3700	-
A2	-283575	-	-241680	-	-59533	-	138550	-
A3	2855050	450606	2144600	428117	355767	98228	-1530100	505770
A4	-15077900	2472520	-10150200	2120690	-1037160	282257	8375630	2505340
A5	46807900	8098800	28262600	5980000	1601510	415074	-25586500	7064650
A6	-89366400	16689500	-47610800	10000200	-1234260	302227	45491800	11814100
A7	105326000	21890700	47599300	9811160	372432	86360	-46672000	11590700
A8	-73886000	17767900	-25934500	5214510			25580500	6160320
A9	27857800	8143520	5920340	1158410			-5794180	1368520
A10	-4244170	1611790						

(Notes: all the estimated parameters are significant at the 1% level)

Seasonally estimated monthly average placements for 12 years are shown against actual monthly average placements in figure 2.3 for placement weight classes less than 600 lbs. In general, the estimated seasonality fits the data reasonably well, although the estimates tend to undershoot the peaks and troughs, which is not unusual for time series models. However, the seasonally adjusted placement data has a smother figure than the original one. The pattern turns out very similar for the all the four weight classes. The other weight classes are shown in Appendix A. For more accuracy, to compare with the estimation of the seasonality by using the whole data set from December 1995 to December 2007, this thesis also considered the possibility of a different polynomial order every quarter from January 2006 to December 2007. However, the results were the same to those found through December 2005 (i.e. appropriate order using Schwartz Criteria Values in table 2.1 are the same).

Figure 2. 4: Comparison of actual and seasonally adjusted monthly average placement data for placement weights less than 600 lbs (steers and heifers)



2.2.4 Transforming monthly placement data to weekly data

Because feedlot placement data are available monthly and slaughter numbers are weekly, the monthly placement data needs to be converted to weekly so that the rank of data will be the same for all variables. Two approaches considered for transforming the data from monthly to weekly are: keeping a constant value for all weeks in the month (an approach whereby the monthly data is simply divided by 4.333(52/12), or the average number of weeks in a month) or allocating placements using the estimated seasonal pattern. Weekly data generated by disaggregating the monthly against a weekly average number of 4.333 will be identified as the "WP" placements model.

Due to monthly variations in the actual data, adjustments can be made to different weeks in the month using a parallel (absolute quantity) shift to the estimated seasonal pattern or a non-parallel shift whereby a percentage adjustment is made relative to the seasonal pattern. That is, if actual placements for month t exceed what would be expected for levels that existed the prior month, weeks with a higher estimated seasonality in month t would receive a larger allocation of the "excess placements" that occurred during month t. In order to allocate actual monthly placements 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. In making these allocations, consideration needs to be made for the number of weeks and days in each week for a month. For example, there are 31 days in a month, 2 days in the first week, 1 day in the last week of that month, and 4 full weeks in between, so, this month spread out for 6 weeks and first week of next month will have 6 days. Thus, the allocation for the first 2 days of this month is generally different than for the first 6 days of next month, due to differences in monthly placements for these months.

Table 2.4 provides an example to show how the monthly seasonal adjusted data is transformed into weekly according to percentage by using solver function in excel (PA). There are several equations constrained to fulfill the solver function. First, weekly seasonality is generated from the results of monthly seasonality.

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

Where *q* and *a* are obtained from equation 2.4, which are shown in table 2.2 and 2.3 accordingly. And m_{wt} is a time indicator which equals days of the year/365 or 366. After weekly seasonality, S_{wt}^{q}, is defined, then the weekly placement shown in columns 1 to 6 (week 1 to week 6 in a month) will be defined as:

$\text{Placement}_{wt} = \text{Percentage}_{mt} * \{(\text{days in the week}_t/7)*[(\text{actual placement}_{mt} + (S^q_{wt} - S^q_{w(t-1)})]\}$ (2.7)

Thirdly, set up the target cell as: $\sum_{wk1}^{wk6} Placement_{wt} - \hat{Q}_{mt} = 0$ (2.8)

where $\hat{Q}_{mt}$ is the seasonally adjusted monthly placement obtained from equation (2.5). Subscript *mt* means month t while *wt* means week t. And finally, the summation of target cells must equal zero so that placements for all weeks equal those placed in the month.

Table 2.4: Example of transforming monthly to weekly data by percentage method

Wk_1	Wk_2	Wk_3	Wk_4	Wk_5	Wk_6	Total wk_1 to wk_6	Percentage	target cell = 0 when solved
88.5405	105.183	96.3829	83.9092	43.8838	0	417.8997	0.185833077	0.0000
18.35	33.3274	26.9445	23.537	16.1569	0	118.3159	0.183482193	0.0000
15.8211	56.2646	58.405	60.9864	63.4195	9.10451	264.0011	0.242276162	0.0000
54.2369	64.5354	65.2134	65.4668	28.0711	0	277.5237	0.235502076	0.0000
27.1009	47.5078	47.8263	48.5311	42.4303	0	213.3964	0.232398251	0.0000
								Sum = 0

For the absolute value transformation (SA), instead of a percentage adjustment as shown in table 2.4, a starting point for the month will be defined and the equation (2.7) will be expressed as:

$\text{Placement}_{wt} = (\text{days in the week}_t/7)*[(\text{defined starting point}_{mt} + (S^q_{wt} - S^q_{w(t-1)})]$ (2.8).

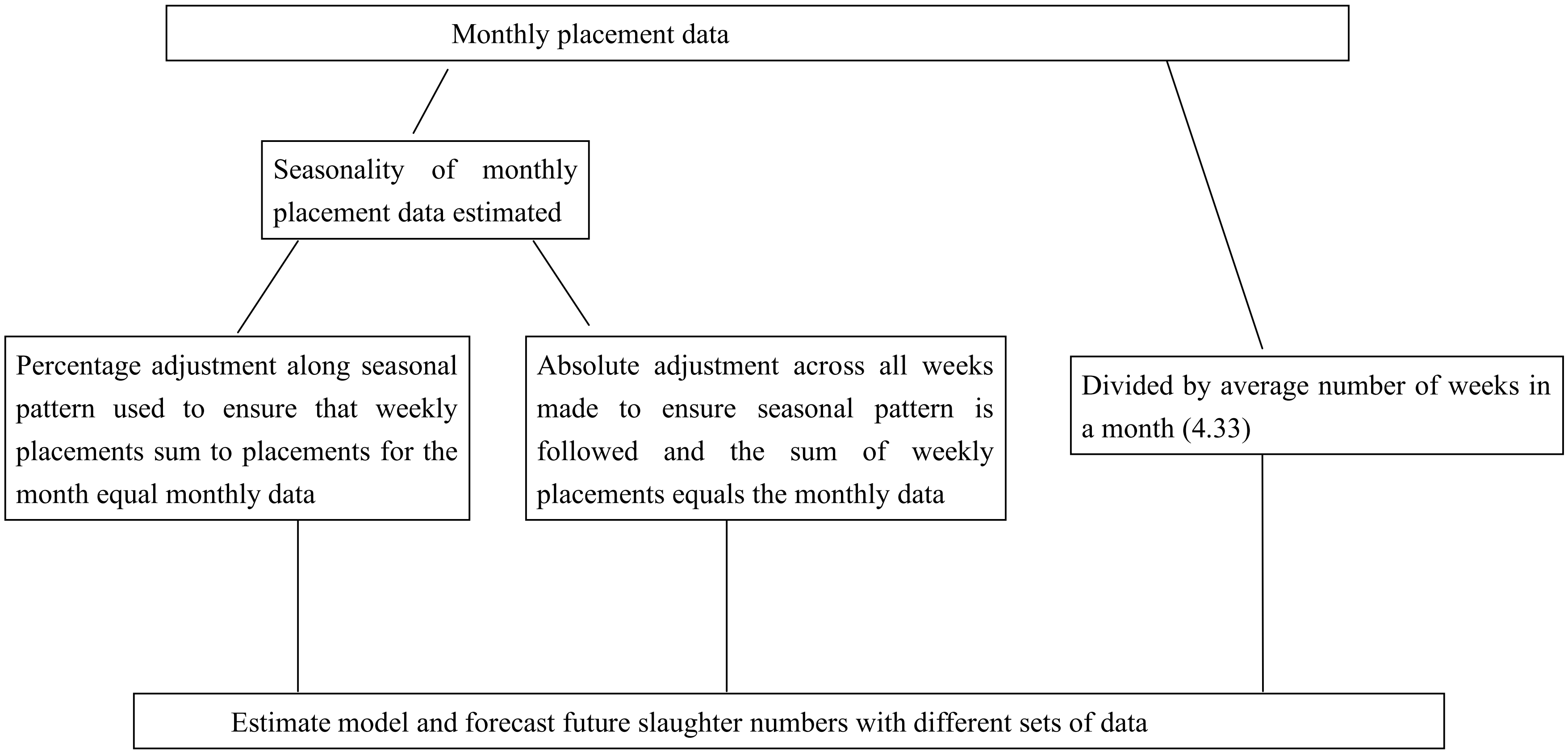
To compare with percentage adjustment and absolute value adjustment, weekly average placement (WP) is obtained in an easier way.

$WP_{wt} = Q_t/(52/12)$, Q_t is actual monthly placement without seasonal adjustment. The result from September 2007 to December 2007 for three approaches is shown in table 2.5. In week 1 or week 6, the amount appears to be comparatively small because fewer days exist in those weeks for the particular month. For example, if a month has 31 days and crosses 6 weeks, there are 2 (or 1) days in the first week and 1 day (or 2) for the last week. When aggregated to 7 days in a week, the first week will be added back to the previous week of last month or the last week will be added to the next week of the coming month. It depends on in which month, there are more days shared.

Table 2.5: Comparison of three sets of weekly placements for placement weights less than 600 lbs (Sep. 2007 to Dec. 2007)

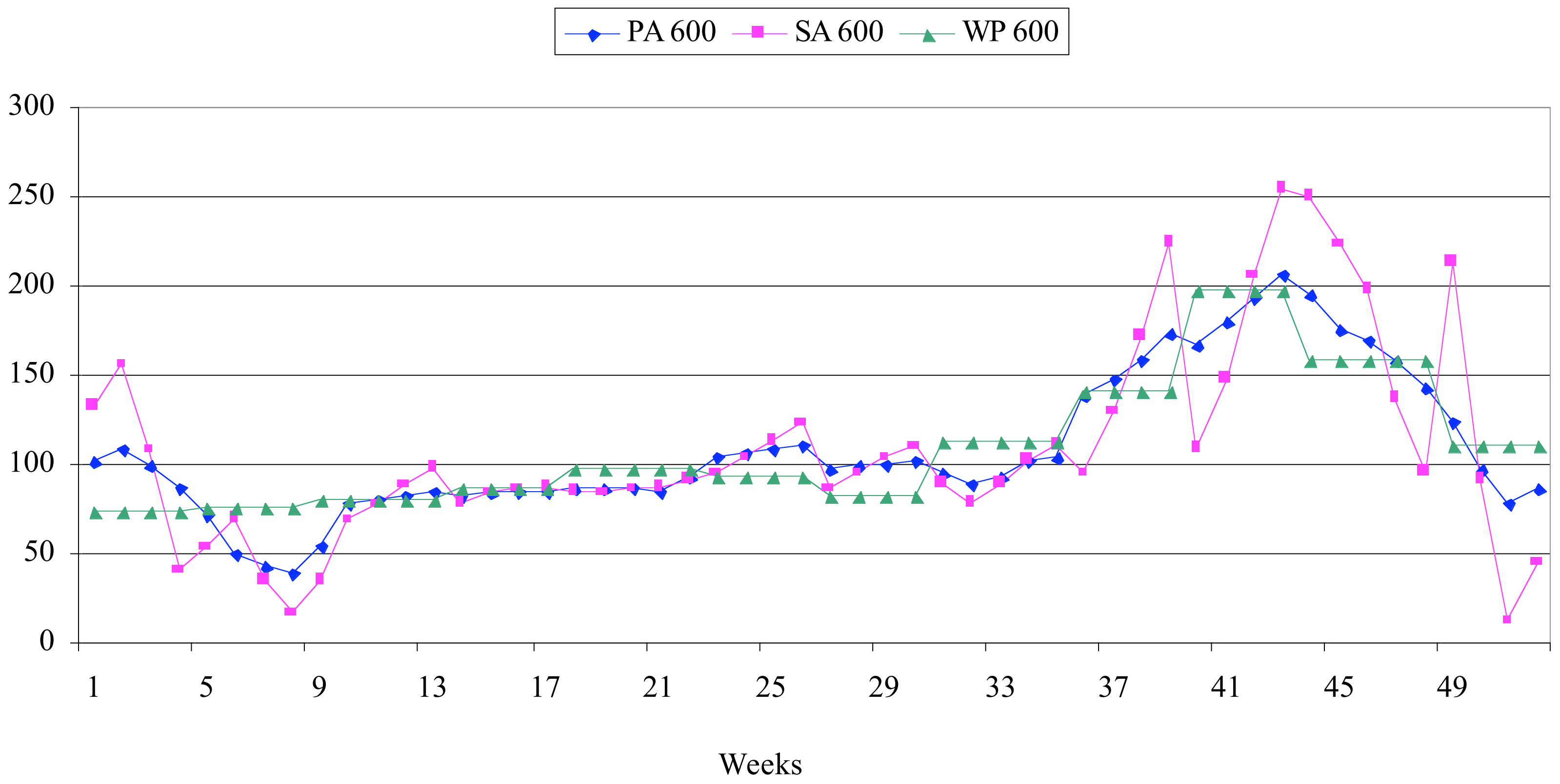
	Seasonal Adjusted Monthly Placement / Original Monthly Placement without Seasonal Adjustment	Weekly Placement	week 1	week2	week 3	week 4	week 5	week 6
Sep. 2007	661.62/610	PA	18.77	138.37	147.58	159.12	172.81	24.99
		SA	9.71	94.26	128.85	172.16	223.57	33.07
		WP	140.77	140.77	140.77	140.77	0.00	0.00
Oct. 2007	841.39/855	PA	141.06	179.58	193.97	206.07	120.71	0.00
		SA	75.52	148.27	205.92	254.45	157.22	0.00
		WP	197.31	197.31	197.31	197.31	0.00	0.00
Nov. 2007	697.39/685	PA	74.26	174.66	169.68	157.51	121.27	0.00
		SA	92.35	222.40	197.51	136.64	48.49	0.00
		WP	158.08	158.08	158.08	158.08	158.08	0.00
Dec. 2007	433.42/480	PA	21.54	123.69	96.43	78.61	85.84	27.31
		SA	47.53	212.57	91.49	12.34	44.44	25.04
		WP	110.77	110.77	110.77	110.77	0.00	0.00

Figure 2.6: Graphical illustration of data and estimation steps.



Weekly placements calculated as a percentage share in a month are defined as "PA" whereas those adjusted with an absolute or parallel seasonal shift are defined as "SA". Three sets of weekly placement data are shown in figure 2.5. The result is what we would expect with "WP" at the same level for every week in a month; "PA" is more smoothly distributed due to the percentage adjustment that changes the slope; and "SA" has parallel shifts that are more pronounced.

Figure 2.7: Comparison of three sets of weekly placements for placement weights less than 600 lbs (from Jan. 2007 to Dec. 2007)



CHAPTER 3: U.S. FED CATTLE MARKET

3.1 Slaughter number estimates

Dressed beef production can be estimated as the product of slaughter numbers and the average slaughter weight. For estimating beef production, at least two empirical models need to be considered, one is for the quantity of beef slaughtered and another is for the average slaughter weight. First, the estimation of slaughter numbers will be discussed.

3.1.1 Empirical model

The model used for estimating slaughter numbers is a polynomial distributed lag function of placements from all weight categories, the natural log of the price ratio of fed steer and corn prices, the choice to select price spread and the price of corn. The polynomial distributed lag (PDL) model which parameterizes the lag coefficients as functions of a few underlying parameters is a practical approach to the problem of fitting the model with long lags in a relatively short time series (Greene 2002). When a long lag length is expected, severe multi-colinearity may occur without using something like a PDL model. And the relatively low degrees of freedom utilized can facilitate more robust results. In this thesis, the lag length is estimated rather than fixed and we focus on the case where the degree of the polynomial is fixed. The model for the total federal inspected slaughter number of steers and heifers is as follows:

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i}\alpha_{ij}PA_{i_{t-j}} + \sum_{k=s_1}^{s_2}\beta_k \ln ratiopsc_{t-k} + \sum_{l=p_1}^{p_2}\delta_l \ln ratiopchc_{t-l} + \sum_{h=1}^{2}\sum_{o=q_1}^{q_2}\gamma_o holiday_{t-o} + \varepsilon_t$$

subject to:

$$\alpha_{ij} = \sum_{m=0}^{n} a_{im}\left(\tfrac{j+1}{P+1}\right)^m, \quad \beta_k = \sum_{m=0}^{n} b_m\left(\tfrac{k+1}{P+1}\right)^m, \quad and \quad \delta_l = \sum_{m=0}^{n} d_m\left(\tfrac{l+1}{P+1}\right)^m, \quad (3.1)$$

where α_j, β_k, δ_l are approximated by a second-degree polynomial (i.e., n = 2) in the length of lags j, k and l respectively, as:

$$\alpha_{ij} = a_{i0} + a_{i1}\left(\tfrac{j+1}{p+1}\right) + a_{i2}\left(\tfrac{j+1}{p+1}\right)^2, \quad \beta_k = b_0 + b_1\left(\tfrac{k+1}{p+1}\right) + b_2\left(\tfrac{k+1}{p+1}\right)^2, \quad and \quad \delta_l = d_0 + d_1\left(\tfrac{l+1}{p+1}\right) + d_2\left(\tfrac{l+1}{p+1}\right)^2,$$

In the above model, $FITOT_t$ is the total federally inspected slaughter numbers of steers and heifers at time *t*. PA_i is the weekly placement based on the percentage transformation of seasonally adjusted monthly placement, and i denotes each of the four feedlot placement weight categories (less than 600 lbs., 600 to 699 lbs., 700 to 799 lbs., 800 lbs. or more). The variable *lnrationpsc* is the log of the ratio of the fed steer price (\$/cwt.) and corn price (\$/bu). The variable *lnratiopchc* is the log of the ratio between the choice minus the select price spread and the price of corn. Dummy variables refer to national holidays which include either a 1- day holiday or 2- day holiday. The letters of r_i, s, p, and q are the appropriate lag periods with respect to the weekly time period, while ε_t is the error term. The others terms are parameter estimates. There may be autocorrelation in the errors, since in a time series the system generally has memory such that the value of an economic variable at any instant in time is affected in varying degrees by the past values in time of that variable: this is the reason why autocorrelation exists in an economic time series. Thus, an autoregressive model of a first order (model AR1) is used to capture this autocorrelation. Similar to model (3.1), in the following models (3.2) and (3.3), slaughter numbers are an equation of placements and the log of the price ratios of steer and corn, choice-select and corn, and holiday dummies as:

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i}\alpha_{ij} SA_{i_{t-j}} + \sum_{k=s_1}^{s_2}\beta_k \ln ratiopsc_{t-k} + \sum_{l=p_1}^{p_2}\delta_l \ln ratiopchc_{t-l} + \sum_{h=1}^{2}\sum_{o=q_1}^{q_2}\gamma_o holiday_{t-o} + \varepsilon_t$$

Where $\alpha_{ij} = \sum_{m=0}^{n} a_{im}\left(\frac{j+1}{P+1}\right)^m, \quad \beta_k = \sum_{m=0}^{n} b_m\left(\frac{k+1}{P+1}\right)^m, \quad and \quad \delta_l = \sum_{m=0}^{n} d_m\left(\frac{l+1}{P+1}\right)^m,$ (3.2)

$$FITOT_t = \sum_{i=1}^{4}\sum_{j=0}^{r_i}\alpha_{ij} WP_{i_{t-j}} + \sum_{k=s_1}^{s_2}\beta_k \ln ratiopsc_{t-k} + \sum_{l=p_1}^{p_2}\delta_l \ln ratiopchc_{t-l} + \sum_{h=1}^{2}\sum_{o=q_1}^{q_2}\gamma_o holiday_{t-o} + \varepsilon_t$$

where $\alpha_{ij} = \sum_{m=0}^{n} a_{im}\left(\frac{j+1}{P+1}\right)^m, \quad \beta_k = \sum_{m=0}^{n} b_m\left(\frac{k+1}{P+1}\right)^m, \quad and \quad \delta_l = \sum_{m=0}^{n} d_m\left(\frac{l+1}{P+1}\right)^m,$ (3.3)

However, the difference in equations (3.2) and (3.3) from (3.1) is with the weekly placement number. In (3.2), the absolute or parallel shift (SA_i) in seasonality is used to transform monthly placements to weekly placements. And to compare with (3.1) and (3.2), equation (3.3) is not adjusted with seasonality, which is WP_i. The seasonality of slaughtering was considered but it is not included in the model, largely because seasonality occurs in the placements and the federally inspected slaughter numbers did not have statistically significant seasonality.

3.1.2 Expected relationships between slaughter numbers and other variables

As mentioned before, steers and heifers being slaughtered each week were placed into feedlots some time in the past. The question is, how much time back? That is, the j, k, and l, indicators in the model need to be estimated. Based on the knowledge of biological growth for the animals, the average slaughter weight of steers and heifers is around 1200 lbs, and steers and heifers usually gain 3 lbs per day. So, for placement weights less than 600 lbs, it takes approximately takes 23 to 46 weeks to reach their target weight. For the class which is in the range of 600 to 699 lbs., it may need around 19 to 37 weeks, and similarly 14 to 32 weeks for 700 to 799 lbs, and 10 to 27 weeks for more than 800 lbs. When those approximate time periods are known, the lagged period in the estimating model can be tested according to those periods. The expected sign for the parameters of placements are positive. If more steers and heifers are placed in the feedlots at earlier periods, there will be more supplies in the slaughter market at current time t than when those steers and heifers reach the target weight.

Considering the parameters of the price ratio of fed steer and corn (gain – cost ratio), the signs will not be simply positive or negative. Because the independent variable of the price ratio combine two economic effects together, both positive and negative relations to the dependent variable exist. If the price of fed steers (or heifers) goes up (the price ratio will increase), the cattle feeders would like to send the steers and heifers to slaughter market to gain more benefit from higher price immediately. The slaughter numbers will go up too: this follows the simple economic concept that the supply increases when prices go up. The same outcome occurs if corn prices increase: as feedstuff costs increase the return associated with feeding at a heavier weight decreases. Because cattle feeders have some in storage, it may take a few weeks of higher corn prices to affect feeding activities. The influence of higher corn price may be felt several weeks later. Also, when the ratio between the price of steer and corn price increase is mainly due to an increase in the fed steer price, slaughter numbers will increase. In addition, the reaction to the slaughter market price will be quicker than the reaction to the corn price, and the expected relationship between slaughter quantities and the price ratio of fed steers and corn is positive for the current periods.

On the other hand, considering the case where the corn price declines, but the fed steer price remains the same, or decreases not as much as corn price, the ratio between those two prices will still increase but may lead to an opposite economic reaction. That is, the cattle feeders will keep the steers and heifers in feedlots instead of send them slaughter market because of the lower cost of feeding. Moreover, the lower price of corn may not have an immediate effect on cattle feeding and slaughter markets accordingly, because the cattle feeders buy corn to support the next few periods of feeding, which means that the lower price of a few earlier periods significantly affects the current market. As a consequence, the price ratio of fed steers and corn from a few periods back is expected to negatively impact current slaughter numbers.

When combining the upper two economic phenomena, the increase in the price ratio of fed steers and corn has a positive influence on slaughter numbers during the current period, but a negative one on the current period if a few more periods back (i.e., lag) are considered.

Similarly to the price of fed steers, the choice-select price spread is an important determinant of returns for beef production. The choice to select price spread measures the price premium for quality, in the form of beef with more marbling or intramuscular fat that produces desirable tenderness, juice, and taste attributes for most consumers. Choice beef is generally more desirable and expensive than select beef. If cattle are fed to a heavier weight, a higher percentage will generally grade choice. The relationship of the ratio of this choice to select price spread and corn price to slaughter numbers is the same as that of the price ratio of fed steers and corn. The value to cost ratio plays an important role in deciding when to slaughter fed cattle. Using similar logic as above, when the ratio goes up, slaughter numbers will go up in current periods due to a higher price but this pulls back supplies from later periods (i.e. a few more lags).

When a holiday is coming, including one-day and two-day holidays, the slaughtering plants close down so that numbers will decrease sharply on holidays. Furthermore, the week before and after holidays may also be influenced, especially for two-day holidays like Thanksgiving and Christmas. Holiday effects may last longer for two- than one-day holidays.

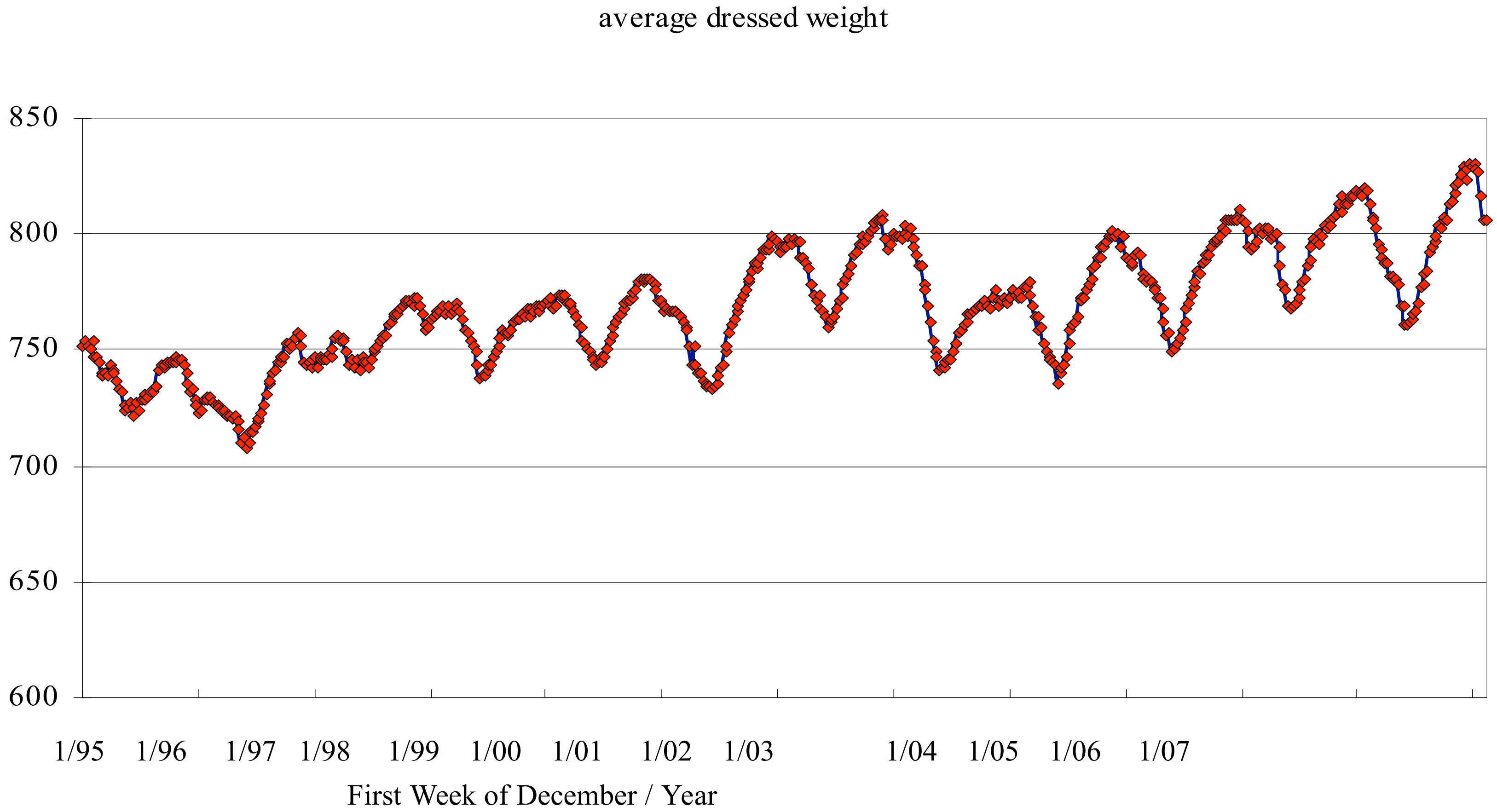
3.2 Slaughter weights

There are several factors which likely influence slaughter weights. Biologically, steers will be fed to heavier weights than heifers. Thus, the percentage of fed animals slaughtered that are steers will impact average slaughter weights. In addition, the cost of gain and holidays are hypothesized to have impact slaughter weights, which will be tested in the full model for slaughter weight.

3.2.1 Full model for slaughter weight

As shown in figure 3.1, the weekly average dressed weight of slaughtered steers and heifers exhibit a strong seasonal pattern in the period from December 1995 to December 2007. Average dressed weights increase gradually through period and exhibit a recurring cyclical pattern for each calendar year. A few weeks before December, the average dressed weight is the greatest, while it is in the middle of the year that the average dressed weight is the lowest for each year. This seasonal cycle requires consideration of seasonality when estimate the average dressed weight in the model. The seasonality of average dressed weights will be estimated within the empirical model of average dressed weights.

Figure 3.1: Weekly average dressed weight (lbs) of slaughtered steers and heifers, December 1995 to December 2007



This full model for average dressed weight of slaughtered steers and heifers is represented as:

$$Avgweight_t = B_0 + B_1 fispercent(t-1) + \sum_{f=0}^{u} G_f ratiopchc_{t-f} + \sum_{g=0}^{v} H_g ratiobeefcorn_{t-g}$$
$$+ \sum_{n=1}^{2} \sum_{r=(-1)}^{1} K_r holiday_{t-r} + \sum_{j=1}^{q} A_j m_t^{\ j} + \varepsilon_t$$

subject to the constraints:

$$\sum_{j=1}^{q} A_j = 0, \qquad and \qquad \sum_{j=2}^{q} jA_j = 0. \qquad (3.4)$$

where *avgweight* is the dressed average beef produced for steers and heifers, *fispercent* is the percentage of steers slaughtered during the week as the sum percentage of slaughtered steers and heifers should be one. The variable *ratiopchc* is the price ratio between the choice-select spread and corn, and *ratiobeefcorn* is the price ratio of beef and corn. One-day or two-day holidays are represented through dummy variables, where 1 represents holidays and otherwise it is zero. Also, m_t is simply the number of weeks of the year divided by 52 (or a time index for seasonality that cycles between 0 and 1*), f, g* and *r* are the lag order, and *j* is the polynomial order for seasonality. As before, the constraints ensure that the seasonal pattern will be continuous and smooth. Other variables are parameters that need to be estimated.

3.2.2 Expected relationship between average weight and other variables

Slaughtered steers are heavier than heifers as discussed above, so that a higher percentage of steers will lead to a heavier slaughter weight. For the choice to select price spread and corn price ratio, a higher ratio means that the profit of feeding is higher so the cattle feeder will feed to a heavier weight to obtain more choice-product. Beef and corn prices are considered as gain vs. cost indicators. If the price ratio between beef and corn increases, cattle feeders may slaughter sooner to take advantage of the higher price of beef, resulting in a lighter average slaughter weight. If there is a holiday, steers and heifers may be kept in the feedlot a few days longer, which will increase their slaughter weight slightly. Also, the seasonal patterns will have very significant relations on slaughter weights.

Results obtained for the full model of average weight show that the model is reasonably estimated, since the R^2 and Durbin-Watson values are very supportive (Table 3.1). The R^2 statistic reported is as follows and provides some information about the goodness of fit of a model:

$$R^2 = 1 - SSE / SST$$

Where SSE is sum of the squared error and SST is the total sum of the squares of the difference of the dependent variable and its mean. An R^2 of 1.0 (as compared to the worst value of 0) indicates that the regression line perfectly fits the data. As described by Green (2007), the Durbin-Watson statistic is a test statistic used to detect the presence of autocorrelation in the residuals from a regression analysis. If e_t is the residual associated with the observation at time t, then the test statistic is:

$$d = \frac{\sum_{t=2}^{T}(e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2} \qquad (3.5)$$

Its value always lies between 0 and 4. A value of 2 suggests there is little autocorrelation. As shown in table 3.1, the Durbin-Watson value of 2.13 indicates that there is no further autocorrelation in the error, and that adjusted R-squared value of .987 indicates the model fits the data well by using an AR1 model.

Table 3.1: Result of statistical criteria used to test the goodness of the full model

R-squared	0.988
Adjusted R-squared	0.987
Durbin-Watson	2.13

Estimated results for average dressed weights also indicate that except for seasonality and the beef-corn price ratio, other independent variables do not have a significant effect on the average weight (Table 3.2). F-test values also show that seasonality has a very strong influence on the average weight and the beef to corn price ratio has a slight effect on it (Table 3.3). From the results of the F-test, it is seen that B_1, the parameter for percentage of slaughtered steers, G_f, the parameters for price ratio of choice-select and corn, and K_r, parameters of holidays, are equal to zero in the 95% interval of hypothesis test. Note that *RHO* is a parameter in autocorrelation of error structure: however, since the model just considers one degree of autocorrelation (i.e. AR1), the parameter significance of *RHO* indicates that the error terms are highly related to the previous period. And the Durbin-Watson Criteria in table 3.1 indicates that the error is not auto-correlated with a second degree structure.

Table 3.2: Estimated results for the full model of average dressed weights

Parameters	Estimated Coefficients	Standard Error	Parameters	Estimated Coefficients	Standard Error
A3	5785.63 ***	569.14	H1	-0.22 **	0.08
A4	-6658.19 ***	654.601	H2	0.05	0.08
A5	2562.19 ***	261.49	H3	0.08	0.08
B0	787.87 ***	17.89	H4	0.04	0.08
B1	0.03	0.08	K1(-1)	0.38	0.32
G0	-0.19	0.42	K1(0)	0.65 *	0.39
G1	-0.44	0.46	K1(1)	0.32	0.34
G2	-0.60	0.48	K2(-1)	-0.38	0.77
G3	0.65	0.48	K2(0)	0.49	0.88
G4	0.02	0.43	K2(1)	0.63	0.73
H0	-0.08	0.08	RHO	0.99 ***	0.01

Note: Single asterisks denote significance at the 10% level; double asterisks denote significance at the 5% level; triple asterisks denote significance at 1% level.

Table 3.3: F-test results

parameters are zero	F value	Critical value(0.95)
$B_1 = 0$	0.14	3.84
$A_j = 0$	67.75	2.60
$G_f = 0$	1.30	2.21
$H_g = 0$	2.36	2.21
$K_o = 0$	0.64	2.10
Joint (keep seasonality and beef/corn price ratio)	0.75	1.67

CHAPTER 4: EMPIRICAL RESULTS AND FORECASTING

4.1 Slaughter numbers

4.1.1 Estimated results

Table 4.1 is the estimated results for slaughter numbers from equation (3.1) by using the seasonally adjusted percentage of weekly placement data from December 1995 to December 2005. The results represent a very logical and reasonable explanation for the relationship between slaughtering and placement amount of steers and heifers. As expected, for placement weights less than 600lbs, the placement of 26 to 48 weeks back from a particular time t will have a significant effect on slaughtering numbers at time t. during those periods where the parameter in the middle period is slightly higher than others (i.e. from week 35 to 45). Also, referring to figure 4.1, the polynomial function distribution for the parameters in the < 600 lb. placement class, is a normal distribution of parameters, where the most effective periods concentrate in the middle period from lag 35 to lag 45 weeks. Similarly, for the placement weight in the 600 lb to 699 lb category, the significant effective period is 19 to 36 weeks, and the higher value of parameters concentrate on week 22 to 31 weeks back from time t;

for the 700-799lb category, all the placements from 12 to 36 weeks back from time t have a significant impact on slaughter numbers in time t, and the greatest impact is from 14 weeks to 25 weeks back. Finally, for the >800 lb. class, placements during 10 to 19 weeks back have a significant effect, and the most effective weeks are from week 10 to week 16. For the variable of placements, all the parameters have small values and are normally distributed through out at least 10 weeks or more. That is because the parameters are distributed with a polynomial function and the constraints on both side of polynomial function are greater than zero. Constraints of greater than zero are imposed since placements for a month cannot be negative. The slaughtered steers and heifers may be from any class of any reasonable time back, so, for each parameter of placements with four weight classes, the effect is not strong but significantly related to slaughter numbers. Also, higher placement weights will have a shorter time in which steers and heifers will be kept in the feedlot, shown in figure 4.1, the middle two weight classes (600-699 lbs and 700-799 lbs) of placement have a greater effect on slaughter numbers since the parameter values are much higher than that of other two weight class of placement. The results of equation 3.2 and 3.3 have a similar pattern with that of equation 3.1. The lag period may be slightly different with each other for the placement variables because of the different method being used to get the weekly placement data. Results are posted in Appendix A and B at the end of this study. By following the statistic criteria of R^2 and Schwartz Criteria Value, the results are the best combination of lags for the four classes of placement.

For the other variables including price ratio and holidays, consistency of the data keeps lag periods the same for every model. As expected, variables *lnratiopsc* and *lnratiopchc*, the price ratio between fed steers and corn, choice-select spread and corn, have positive signs for the current few weeks and then change to a negative sign for a few more weeks back, which are expected to be. For the holidays, there is a very significant drop in slaughter numbers if a holiday occurs, especially for two-day holidays, where the drop is double the size for a one-day holiday. Also, the holiday effect can start from one week back which is also more significant for two-day holidays.

Table 4.1: Estimated results by using seasonally adjusted weekly placement data

Mean of dep. Var.	541.4	R-squared	0.708
Std. dev. Of dep. Var.	46.9	Adjusted R-squared	0.696
Sum of squared residuals	303256	Durbin-Watson	2.18
Variance of residuals	672.4	Schwartz B.I.C.	2245.59
Std. error of regression	25.9	Log likelihood	-2187.14

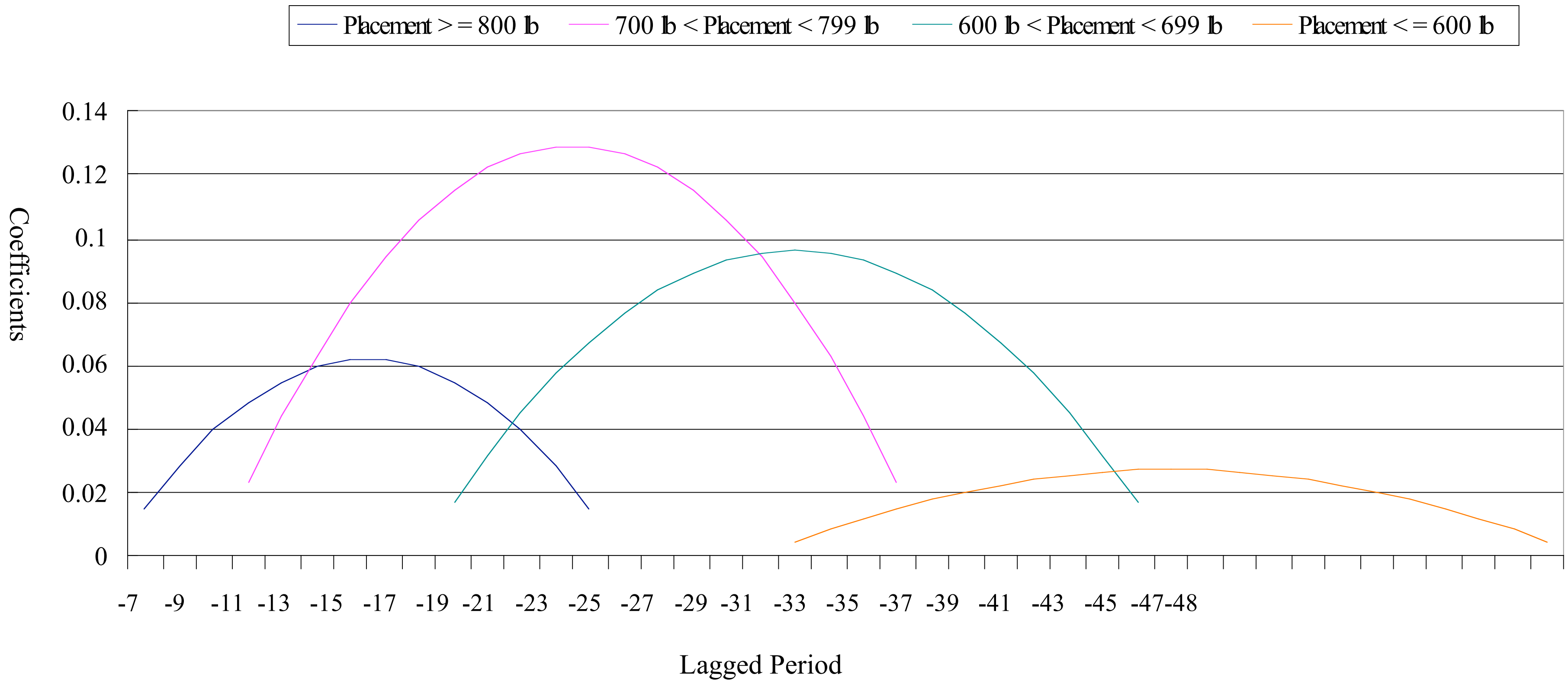
Variables	Estimate Parameters	Standard Error	Parameters	Estimated Parameters	Standard Error
PA600(-26)	0.004***	0.001	PA799(-21)	0.127***	0.012
PA600(-27)	0.008***	0.002	PA799(-22)	0.122***	0.011
PA600(-28)	0.012***	0.003	PA799(-23)	0.115***	0.011
PA600(-29)	0.015***	0.003	PA799(-24)	0.106***	0.010
PA600(-30)	0.018***	0.004	PA799(-25)	0.094***	0.009
PA600(-31)	0.021***	0.004	PA799(-26)	0.080***	0.007
PA600(-32)	0.023***	0.005	PA799(-27)	0.063***	0.006
PA600(-33)	0.024***	0.005	PA799(-28)	0.045***	0.004
PA600(-34)	0.026***	0.005	PA799(-29)	0.023***	0.002
PA600(-35)	0.027***	0.006	PA800(-7)	0.015***	0.004
PA600(-36)	0.027***	0.006	PA800(-8)	0.029***	0.007
PA600(-37)	0.027***	0.006	PA800(-9)	0.040***	0.009
PA600(-38)	0.027***	0.006	PA800(-10)	0.048***	0.011
PA600(-39)	0.027***	0.006	PA800(-11)	0.055***	0.013
PA600(-40)	0.026***	0.005	PA800(-12)	0.059***	0.014
PA600(-41)	0.024***	0.005	PA800(-13)	0.062***	0.015
PA600(-42)	0.023***	0.005	PA800(-14)	0.062***	0.015
PA600(-43)	0.021***	0.004	PA800(-15)	0.059***	0.014
PA600(-44)	0.018***	0.004	PA800(-16)	0.055***	0.013
PA600(-45)	0.015***	0.003	PA800(-17)	0.048***	0.011
PA600(-46)	0.012***	0.003	PA800(-18)	0.040***	0.009
PA600(-47)	0.008***	0.002	PA800(-19)	0.029***	0.007
PA600(-48)	0.004***	0.001	PA800(-20)	0.015***	0.004
PA699(-16)	0.017***	0.002	LNRATIOPS C	28.799**	12.929
PA699(-17)	0.032***	0.003	LNRATIOPS C(-1)	17.907**	7.747
PA699(-18)	0.045***	0.005	LNRATIOPS	8.795**	3.483

			C(-2)		
PA699(-19)	0.057***	0.006	LNRATIOPSC(-3)	1.464	0.922
PA699(-20)	0.068***	0.007	LNRATIOPSC(-4)	-4.087	2.842
PA699(-21)	0.076***	0.008	LNRATIOPSC(-5)	-7.857*	4.501
PA699(-22)	0.083***	0.008	LNRATIOPSC(-6)	-9.846*	5.330
PA699(-23)	0.089***	0.009	LNRATIOPSC(-7)	-10.056*	5.299
PA699(-24)	0.093***	0.009	LNRATIOPSC(-8)	-8.484*	4.402
PA699(-25)	0.095***	0.010	LNRATIOPSC(-9)	-5.132*	2.636
PA699(-26)	0.096***	0.010	LNRATIOPCHC	9.968***	2.118
PA699(-27)	0.095***	0.010	LNRATIOPCHC(-1)	6.074***	1.354
PA699(-28)	0.093***	0.009	LNRATIOPCHC(-2)	2.824***	0.804
PA699(-29)	0.089***	0.009	LNRATIOPCHC(-3)	0.218	0.598
PA699(-30)	0.083***	0.008	LNRATIOPCHC(-4)	-1.744**	0.715
PA699(-31)	0.076***	0.008	LNRATIOPCHC(-5)	-3.063***	0.878
PA699(-32)	0.068***	0.007	LNRATIOPCHC(-6)	-3.738***	0.956
PA699(-33)	0.057***	0.006	LNRATIOPCHC(-7)	-3.769***	0.916
PA699(-34)	0.045***	0.005	LNRATIOPCHC(-8)	-3.157***	0.745
PA699(-35)	0.032***	0.003	LNRATIOPCHC(-9)	-1.900***	0.441
PA699(-36)	0.017***	0.002	H1DAY(-2)	-2.117	5.971
PA799(-10)	0.023***	0.002	H1DAY(-1)	-14.665**	4.784
PA799(-11)	0.045***	0.004	H1DAY	-47.338***	6.173

PA799(-12)	0.063***	0.006	H1DAY(1)	-9.033	5.960
PA799(-13)	0.080***	0.007	H1DAY(2)	-7.349	4.842
PA799(-14)	0.094***	0.009	H2DAY(-2)	-2.872	10.742
PA799(-15)	0.106***	0.010	H2DAY(-1)	-53.417***	9.268
PA799(-16)	0.115***	0.011	H2DAY	-108.479***	11.034
PA799(-17)	0.122***	0.011	H2DAY(1)	-4.359	10.688
PA799(-18)	0.127***	0.012	H2DAY(2)	-18.401*	9.463
PA799(-19)	0.129***	0.012	RHO	0.466***	0.041
PA799(-20)	0.129***	0.012			

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

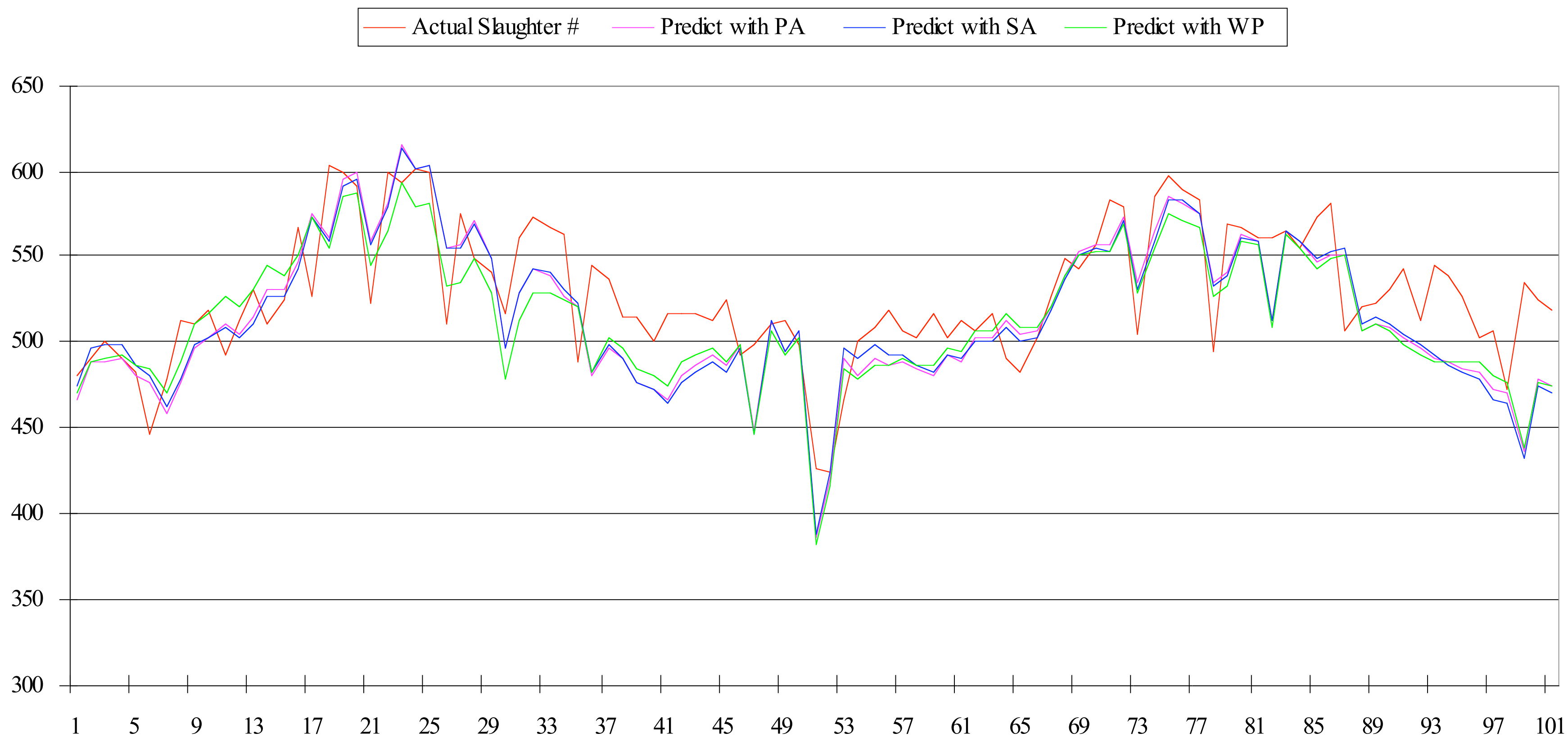
Figure 4.1: 2nd -order polynomial function of estimated coefficients for four classes of placement by using “PA” data.



4.1.2 Forecasting results for slaughter amount model.

Forecasting the estimated results is a way of testing how well each model works. There are three comparable models for slaughtering, respectively shown earlier in equations (3.1), (3.2) and (3.3). The estimation results for equation 3.2 and 3.3 are posted at the end as Appendix A and B. The pattern of the results is close to the one for equation (3.1) which is explained in previous section. There is 1, 4, 8, and 12-week forecasting, which means using the estimated results to forecast what the slaughter amount is for 1, 4, 8 and 12 weeks in the future respectively. The forecasting period is from January 2006 to December 2007. The first estimation is done by using the 10 years of data from December 1995 to December 2005, and then adding 1 more week data to estimate and forecasting with the updated data. The loop process is done continuously to the end of the forecasting period. Figure 4.2, the comparison of the actual weekly slaughter numbers to three sets of one-week forecasting results by using different weekly placement (PA, SA and WP). As stated in an earlier section (figure 2.1), PA and SA are more smoothly adjusted from monthly to weekly data than SA. WP is the original data with placements divided up equally among all weeks during the year. Because all three methods are such that the weekly total for each month are the almost the same (seasonal adjusted vs. non-adjusted monthly placement) and other variables are the same, the three sets of prediction results are very close to each other.

Figure 4.2: Comparison of actual slaughter numbers and three sets of one - week prediction (Jan. 2006-Dec.2007)



However, from the previous figure (figure 4.2), it is very difficult to tell which set of weekly data estimate and forecast better since the graph for each prediction lies very close to each other. Table 4.2 compares the root mean square error (RMSE) for three types of estimating by using “PA”, “SA” and “WP” placement data. RMSE quantifies the amount by which an estimator differs from the true value of the quantity being estimated. A smaller RMSE is preferred. The RMSE in table 4.2 shows that forecasting with the seasonally adjusted data (PA and SA) is better than the non – adjusted data (WP). And within the seasonally adjusted weekly data, the result from using a percentage transformation (PA) is a little better than that of absolute value (SA) transformation. But it is common for all the three groups that the further out in which the forecasting occurs results in a higher RMSE. This is very understandable because it is more difficult to forecast future events that are further away in time.

Table 4.2: RMSE of forecasting result by using different weekly placement data from Jan. 2006 to Dec. 2007

Forecasting	RMSE by using different weekly placement			Percentage of RMSE to the mean of weekly placement		
	PA	SA	WP	PA	SA	WP
Week 1	28.43	28.65	28.83	5.38	5.42	5.46
Week 4	36.60	36.66	37.70	6.91	6.92	7.12
Week 8	39.56	39.53	40.71	7.44	7.43	7.65
Week 12	39.98	40.74	42.22	7.51	7.65	7.93

4.2 Estimation and forecasting results for average slaughtering weight

4.2.1 Restricted model for average weight and estimating results

From the results of the previous section it is shown that the full model of average dressed weight is reasonable, but may not necessary. Since some variables in the full model (3.4) are not significant, the following model just keeps the significant independent variables, seasonality and the price ratio of beef and corn.

$$Avgweight_t = B_0 + \sum_{g=0}^{v} H_g ratiobeefcorn_{t-g} + \sum_{j=1}^{5} A_j m_t^{\ j} + \varepsilon_t \qquad (4.1)$$

Constraints $\sum_{j=1}^{q} A_j = 0$, $\quad and \quad$ $\sum_{j=2}^{q} jA_j = 0.$

The model is estimated and the results are used for forecasting. The estimation result is presented in table 4.3.

Table 4.3: estimating result of restricted model for average slaughter weight

Parameters	Estimated Parameters	Standard Error
B0	792.05 ***	17.19
H0	-0.11	0.07
H1	-0.23 ***	0.07
H2	0.00	0.07
H3	0.09	0.07
H4	0.03	0.07
A3	5845.54 ***	543.05
A4	-6713.68 ***	626.09
A5	2581.39 ***	250.14
RHO	0.99 ***	0.01

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

H1 is the parameter for current week of variable *ratiobeefcorn*, and *H2, H3, H4, H5* represent 1,2,3,4, weeks back from current week. As per the same logic as the earlier section in chapter 3, for the price ratios in slaughter numbers model, the average dressed weight of slaughtered steers and heifers will be influenced mostly by the price of beef at current periods (present week and 1 week back). But with a few more weeks lag, the weight will likely be influenced by the price of corn more due to the length of reaction to the changing of prices. In current weeks, if the beef price increases more than the corn price, it will display cattle feeders trying to send steers and heifers to the slaughter market sooner than otherwise. That is why the parameters have a negative sign for the first two weeks. And the effect in one week back is more significant than present week it is because it takes time to response the price change. A few more weeks back do not have significant on slaughter weight, but the parameter with positive signs are as they are expected. Overall, seasonality is the most significant influence on explaining average slaughter weights.

4.2.2 Forecasting result of restricted model for average slaughter weight

The forecasting results, as shown in table 4.4, almost perfectly match the original data: the Root Mean Square Error (RMSE) is extremely small and the percentage of error is only 1.5% of the actual average dressed weight for all different period of forecasting. This is because seasonality is the dominant variable.

Table 4.4: Root mean square error from forecasting by using the result of restriction model

	1 week forecasting	4 weeks forecasting	8 weeks forecasting	12 weeks forecasting
RMSE	12.01	12.26	12.43	11.96
Percent of Error	1.50	1.54	1.56	1.50

CHAPTER 5: CONCLUSION

After all the estimations and tests, it is very clear that there is a very strong relationship between placement numbers, seasonality, and market forces in determining future slaughter numbers. The results of this study provide important information on how cattle feeders adjust their feeding activity and respond to market signals in delivering animals to slaughter. Given that feedlots are responding to market signals when slaughtering cattle early or feeding to heavier weights, my results suggest that “captive supplies” are not so restrictive that market responses are not occurring.

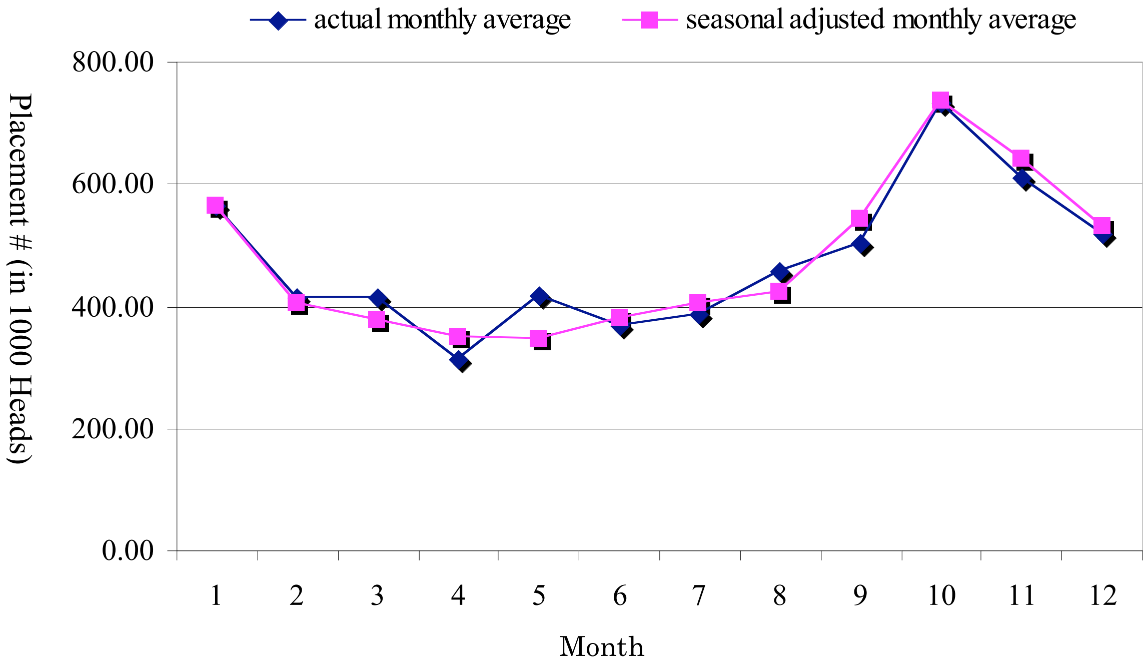
From a macro viewpoint, results can be used to help anticipate or forecast relationships between feedlot placements, future beef supplies, and price forecasts. For example, if the border of Mexico were to shut down so the feeder imports would not occur to the U.S., this model could be used to quantify the impact on beef supplies for several weeks in the future. In a few months after shutting down the border, the influence will manifest itself as a shortage of beef available to U.S. consumers. From a micro viewpoint, the results of price ratios in this study will guide both cattle feeders and beef producers on how to react quickly and correctly if the prices of fed steers, beef and/or corn change.

This study also suggests that for more accurate results, seasonality has to be considered when transforming monthly data to a weekly time frame. There is strong seasonality in placement data for all four classes, and comparatively the seasonality in slaughtering data is not very significant, except for national holiday effects. And the results indicate that seasonally adjusted placement data make a better estimation and forecasting than that without the seasonal adjustment.

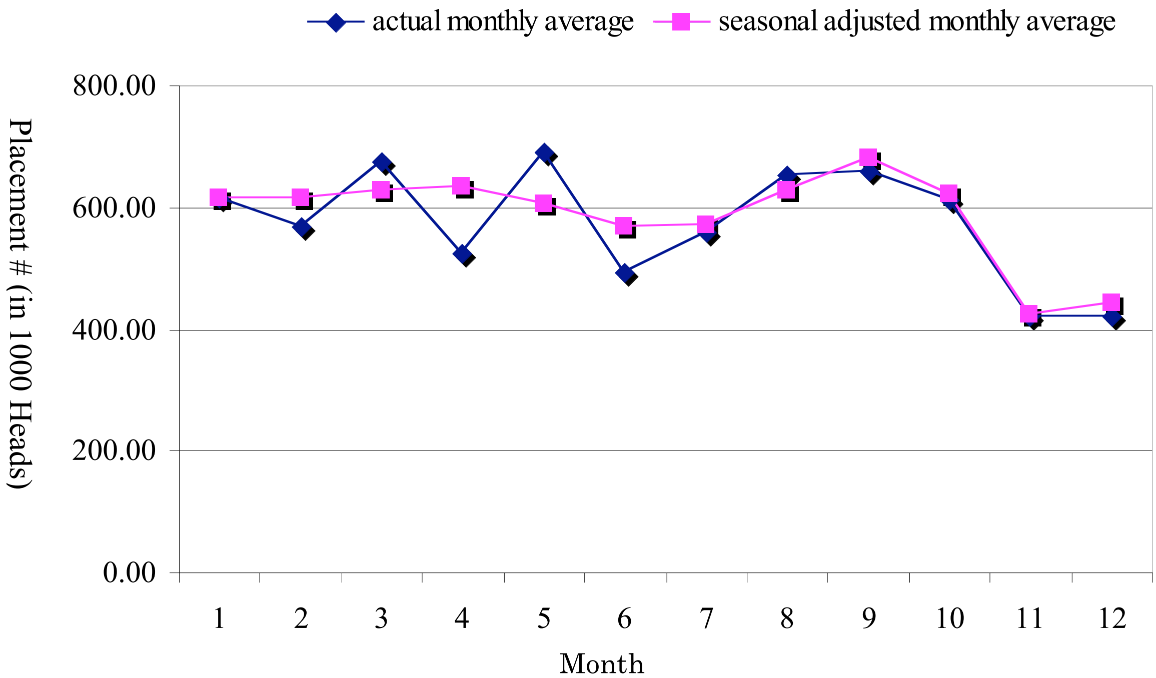
For the average slaughter weight model, seasonality and beef prices have a significant effect on slaughter weights. Because seasonality overwhelms the other variables if the influence of these variables is not strong enough in this study. However, the significance of logarithm of the price ratio of beef to corn indicates that the relative profitability of cattle feeding plays a role in determining slaughter weights.

In this study, in order to match the rank with weekly slaughter numbers, weekly placements are transformed from monthly placement data. Even the optimal results are shown when transforming by using the solver function, this is still not the exactly weekly placement in the U.S. cattle feeding market, which may have a little bias in the weekly data. Overall, results support the notion that USDA’s monthly data has great value in predicting weekly slaughter numbers, particularly when a continuous form of estimated seasonality is accounted for in the transformation.

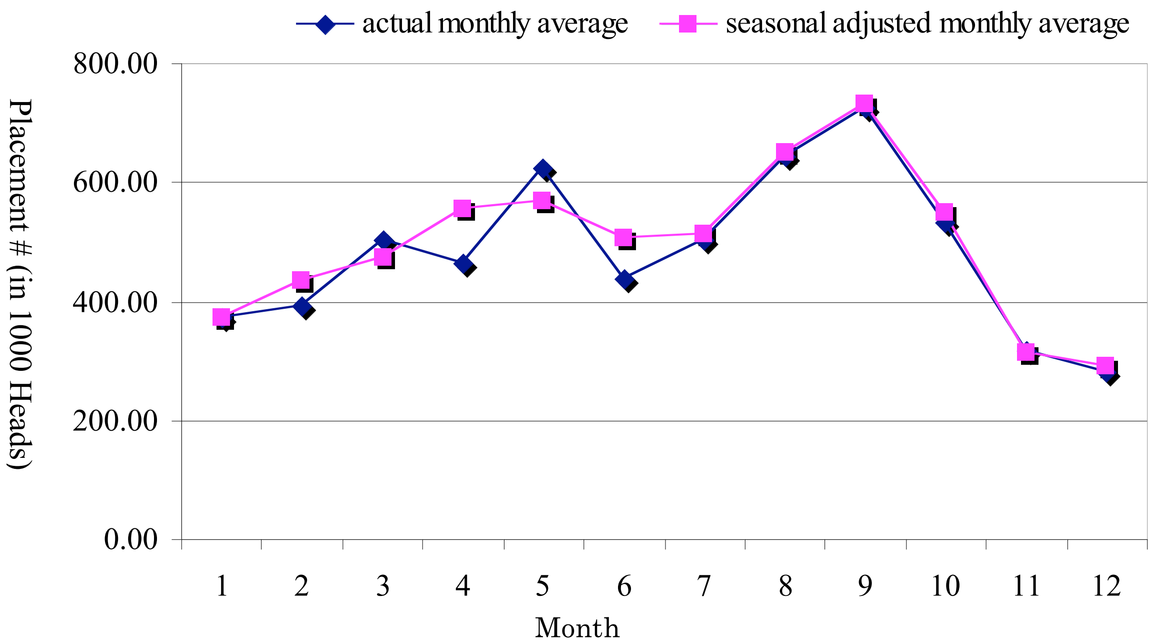
Appendix A (1): Comparison of actual and seasonally adjusted placement data for placement weight less than 600 -699lbs (steers and heifers)



Appendix A (2): Comparison of actual and seasonally adjusted placement data for placement weight less than 700 -799lbs (steers and heifers)



Appendix A (3): Comparison of actual and seasonally adjusted placement data for placement weight greater than 800lbs (steers and heifers)



Appendix B (1): Estimate result by using seasonal adjusted but absolute weekly data.

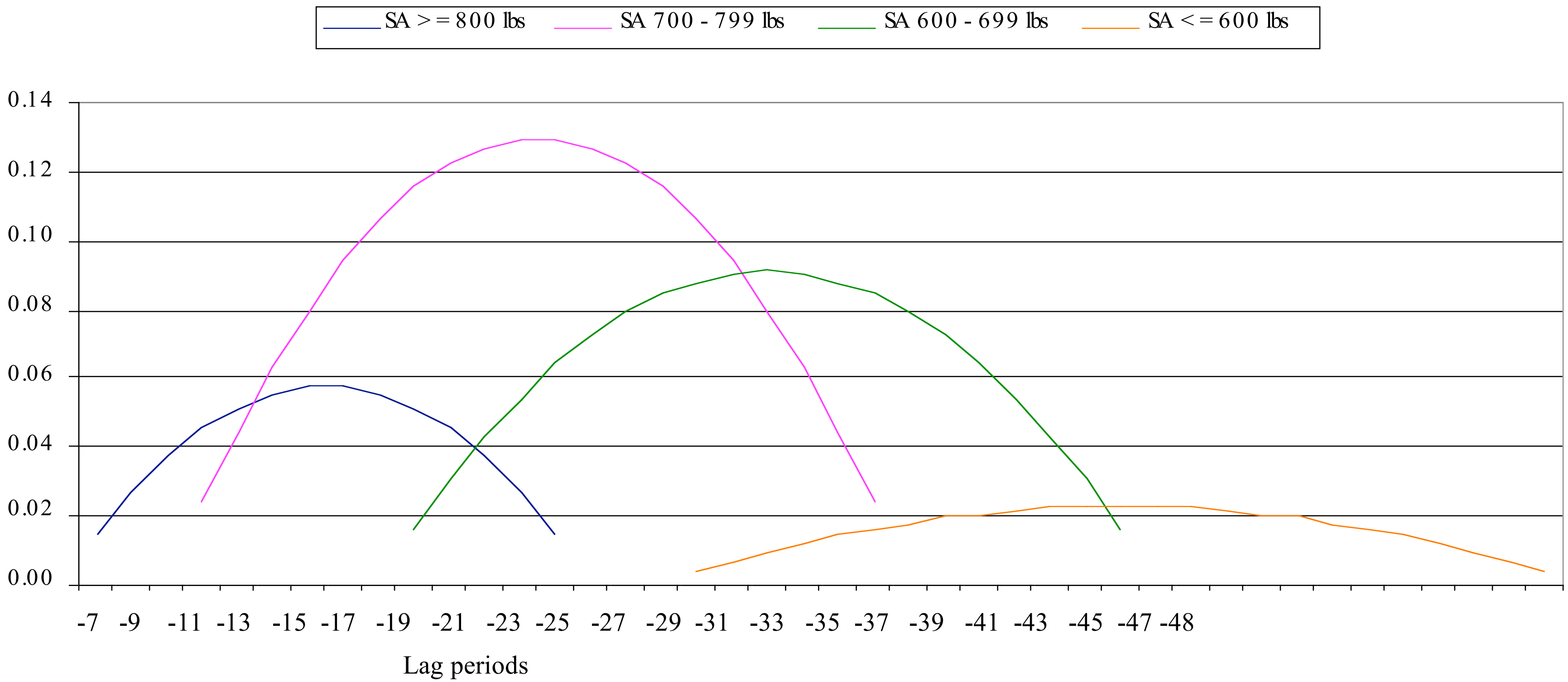
Mean of dep. Var.	541.4	R-squared	0.707
Std. dev. Of dep. Var.	46.9	Adjusted R-squared	0.695
Sum of squared residuals	304424.0	Durbin-Watson	2.18
Variance of residuals	675.0	Schwartz B.I.C.	2246.51
Std. error of regression	26.0	Log likelihood	-2188.06

Variables	Estimate Parameters	Standard Error	Variables	Estimate Parameters	Standard Error
SA600(-24)	0.003 ***	0.001	SA799(-20)	0.130 ***	0.011
SA600(-25)	0.006 ***	0.002	SA799(-21)	0.127 ***	0.011
SA600(-26)	0.009 ***	0.002	SA799(-22)	0.123 ***	0.010
SA600(-27)	0.012 ***	0.003	SA799(-23)	0.115 ***	0.010
SA600(-28)	0.014 ***	0.003	SA799(-24)	0.106 ***	0.009
SA600(-29)	0.016 ***	0.004	SA799(-25)	0.094 ***	0.008
SA600(-30)	0.018 ***	0.004	SA799(-26)	0.080 ***	0.007
SA600(-31)	0.019 ***	0.005	SA799(-27)	0.064 ***	0.005
SA600(-32)	0.021 ***	0.005	SA799(-28)	0.045 ***	0.004
SA600(-33)	0.021 ***	0.005	SA799(-29)	0.024 ***	0.002
SA600(-34)	0.022 ***	0.005	SA800(-7)	0.014 ***	0.003
SA600(-35)	0.023 ***	0.005	SA800(-8)	0.027 ***	0.006
SA600(-36)	0.023 ***	0.006	SA800(-9)	0.037 ***	0.008
SA600(-37)	0.023 ***	0.005	SA800(-10)	0.045 ***	0.010
SA600(-38)	0.022 ***	0.005	SA800(-11)	0.052 ***	0.011
SA600(-39)	0.021 ***	0.005	SA800(-12)	0.056 ***	0.012
SA600(-40)	0.021 ***	0.005	SA800(-13)	0.058 ***	0.013
SA600(-41)	0.019 ***	0.005	SA800(-14)	0.058 ***	0.013
SA600(-42)	0.018 ***	0.004	SA800(-15)	0.056 ***	0.012
SA600(-43)	0.016 ***	0.004	SA800(-16)	0.052 ***	0.011
SA600(-44)	0.014 ***	0.003	SA800(-17)	0.045 ***	0.010
SA600(-45)	0.012 ***	0.003	SA800(-18)	0.037 ***	0.008
SA600(-46)	0.009 ***	0.002	SA800(-19)	0.027 ***	0.006
SA600(-47)	0.006 ***	0.002	SA800(-20)	0.014 ***	0.003
SA600(-48)	0.003 ***	0.001	LNRATIOPSC	31.137 **	13.015
SA699(-16)	0.016 ***	0.002	LNRATIOPSC(-1)	19.634 ***	7.795

SA699(-17)	0.030 ***	0.003	LNRATIOPSC(-2)	9.996 ***	3.496
SA699(-18)	0.043 ***	0.004	LNRATIOPSC(-3)	2.222 ***	0.894
SA699(-19)	0.054 ***	0.005	LNRATIOPSC(-4)	-3.689	2.854
SA699(-20)	0.064 ***	0.006	LNRATIOPSC(-5)	-7.734 *	4.530
SA699(-21)	0.072 ***	0.007	LNRATIOPSC(-6)	-9.916 *	5.367
SA699(-22)	0.079 ***	0.008	LNRATIOPSC(-7)	-10.233 *	5.336
SA699(-23)	0.084 ***	0.009	LNRATIOPSC(-8)	-8.686 **	4.433
SA699(-24)	0.088 ***	0.009	LNRATIOPSC(-9)	-5.275 **	2.654
SA699(-25)	0.090 ***	0.009	LNRATIOPCHC	10.632 ***	2.174
SA699(-26)	0.091 ***	0.009	LNRATIOPCHC(-1)	6.483 ***	1.387
SA699(-27)	0.090 ***	0.009	LNRATIOPCHC(-2)	3.020 ***	0.818
SA699(-28)	0.088 ***	0.009	LNRATIOPCHC(-3)	0.242	0.601
SA699(-29)	0.084 ***	0.009	LNRATIOPCHC(-4)	-1.850 ***	0.722
SA699(-30)	0.079 ***	0.008	LNRATIOPCHC(-5)	-3.256 ***	0.892
SA699(-31)	0.072 ***	0.007	LNRATIOPCHC(-6)	-3.976 ***	0.974
SA699(-32)	0.064 ***	0.006	LNRATIOPCHC(-7)	-4.011 ***	0.935
SA699(-33)	0.054 ***	0.005	LNRATIOPCHC(-8)	-3.359 ***	0.762
SA699(-34)	0.043 ***	0.004	LNRATIOPCHC(-9)	-2.023 ***	0.451
SA699(-35)	0.030 ***	0.003	H1DAY(-2)	-3.771	4.867
SA699(-36)	0.016 ***	0.002	H1DAY(-1)	-16.684 ***	6.145
SA799(-10)	0.024 ***	0.002	H1DAY	-49.184 ***	6.342
SA799(-11)	0.045 ***	0.004	H1DAY(1)	-10.592 *	6.082
SA799(-12)	0.064 ***	0.005	H1DAY(2)	-8.167 *	4.888
SA799(-13)	0.080 ***	0.007	H2DAY(-2)	-5.96	9.316
SA799(-14)	0.094 ***	0.008	H2DAY(-1)	-57.816 ***	10.873
SA799(-15)	0.106 ***	0.009	H2DAY	-112.823 ***	11.214
SA799(-16)	0.115 ***	0.010	H2DAY(1)	-8.01	10.876
SA799(-17)	0.123 ***	0.010	H2DAY(2)	-20.065 **	9.551
SA799(-18)	0.127 ***	0.011	RHO	0.470 ***	0.041
SA799(-19)	0.130 ***	0.011			

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

Appendix B (2): 2nd -order polynomial function of estimated coefficients for four classes of placement by using “SA” data.



Appendix C(1) Estimated results by using non-seasonally adjusted weekly placements

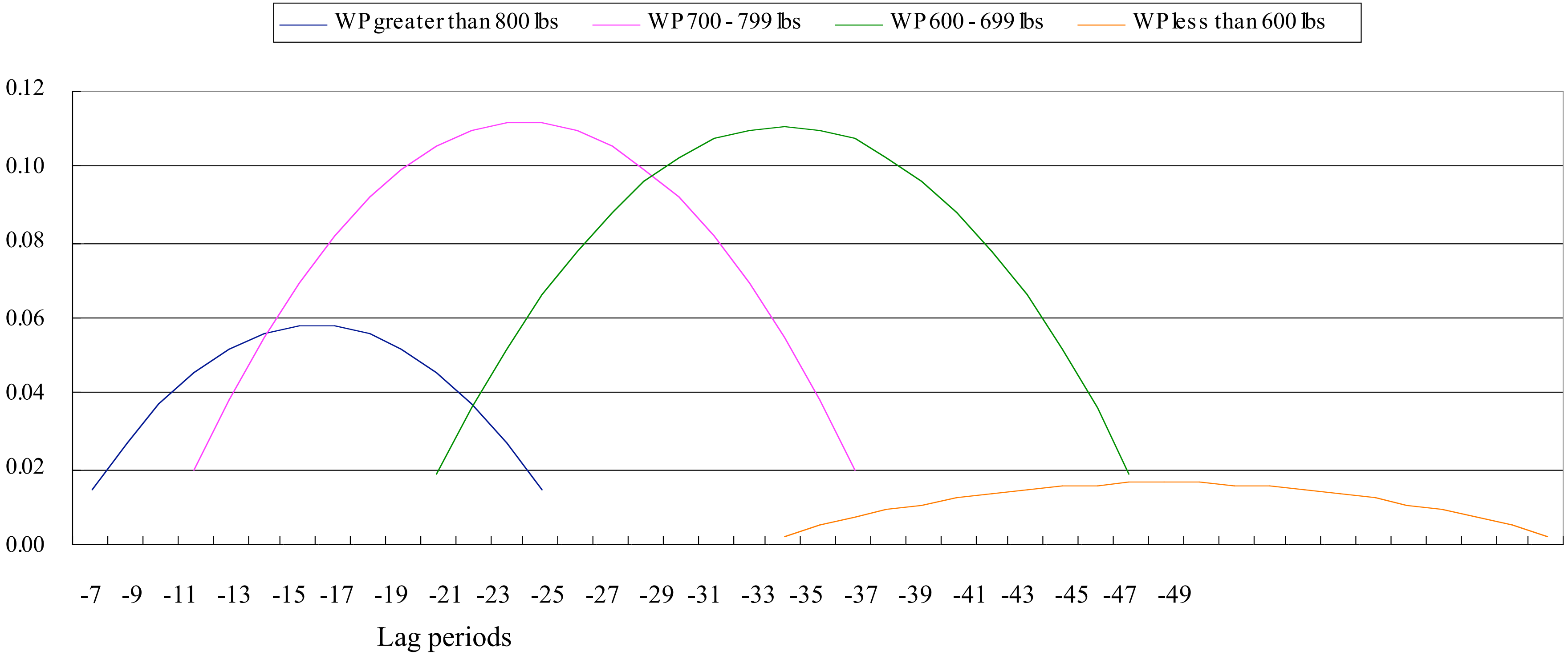
Mean of dep. Var.	541.4	R-squared	0.708
Std. dev. Of dep. Var.	46.9	Adjusted R-squared	0.796
Sum of squared residuals	302520.0	Durbin-Watson	2.18
Variance of residuals	670.8	Schwartz B.I.C.	2245.26
Std. error of regression	25.9	Log likelihood	-2186.80

Variables	Estimate Parameters	Standard Error	Variables	Estimate Parameters	Standard Error
WP600(-27)	0.003 ***	0.001	WP799(-21)	0.110 ***	0.012
WP600(-28)	0.005 ***	0.002	WP799(-22)	0.106 ***	0.011
WP600(-29)	0.007 ***	0.003	WP799(-23)	0.100 ***	0.011
WP600(-30)	0.009 ***	0.003	WP799(-24)	0.091 ***	0.010
WP600(-31)	0.011 ***	0.004	WP799(-25)	0.081 ***	0.009
WP600(-32)	0.012 ***	0.004	WP799(-26)	0.069 ***	0.007
WP600(-33)	0.014 ***	0.005	WP799(-27)	0.055 ***	0.006
WP600(-34)	0.015 ***	0.005	WP799(-28)	0.039 ***	0.004
WP600(-35)	0.016 ***	0.006	WP799(-29)	0.020 ***	0.002
WP600(-36)	0.016 ***	0.006	WP800(-7)	0.014 ***	0.004
WP600(-37)	0.017 ***	0.006	WP800(-8)	0.027 ***	0.007
WP600(-38)	0.017 ***	0.006	WP800(-9)	0.037 ***	0.010
WP600(-39)	0.017 ***	0.006	WP800(-10)	0.045 ***	0.012
WP600(-40)	0.016 ***	0.006	WP800(-11)	0.051 ***	0.014
WP600(-41)	0.016 ***	0.006	WP800(-12)	0.055 ***	0.015
WP600(-42)	0.015 ***	0.005	WP800(-13)	0.057 ***	0.015
WP600(-43)	0.014 ***	0.005	WP800(-14)	0.057 ***	0.015
WP600(-44)	0.012 ***	0.004	WP800(-15)	0.055 ***	0.015
WP600(-45)	0.011 ***	0.004	WP800(-16)	0.051 ***	0.014
WP600(-46)	0.009 ***	0.003	WP800(-17)	0.045 ***	0.012
WP600(-47)	0.007 ***	0.003	WP800(-18)	0.037 ***	0.010
WP600(-48)	0.005 ***	0.002	WP800(-19)	0.027 ***	0.007
WP600(-49)	0.003 ***	0.001	WP800(-20)	0.014 ***	0.004

WP699(-17)	0.019 ***	0.002	LNRATIOPSC	31.042 **	12.871
WP699(-18)	0.037 ***	0.003	LNRATIOPSC(-1)	19.885 ***	7.709
WP699(-19)	0.052 ***	0.005	LNRATIOPSC(-2)	10.518 ***	3.456
WP699(-20)	0.066 ***	0.006	LNRATIOPSC(-3)	2.940 ***	0.865
WP699(-21)	0.078 ***	0.007	LNRATIOPSC(-4)	-2.848	2.813
WP699(-22)	0.088 ***	0.008	LNRATIOPSC(-5)	-6.847	4.473
WP699(-23)	0.096 ***	0.009	LNRATIOPSC(-6)	-9.056 *	5.301
WP699(-24)	0.102 ***	0.010	LNRATIOPSC(-7)	-9.476 *	5.272
WP699(-25)	0.107 ***	0.010	LNRATIOPSC(-8)	-8.107 *	4.380
WP699(-26)	0.110 ***	0.010	LNRATIOPSC(-9)	-4.948 *	2.623
WP699(-27)	0.111 ***	0.010	LNRATIOPCHC	6.767 ***	2.116
WP699(-28)	0.110 ***	0.010	LNRATIOPCHC(-1)	3.803 ***	1.344
WP699(-29)	0.107 ***	0.010	LNRATIOPCHC(-2)	1.348 *	0.786
WP699(-30)	0.102 ***	0.010	LNRATIOPCHC(-3)	-0.599	0.580
WP699(-31)	0.096 ***	0.009	LNRATIOPCHC(-4)	-2.038 ***	0.708
WP699(-32)	0.088 ***	0.008	LNRATIOPCHC(-5)	-2.969 ***	0.879
WP699(-33)	0.078 ***	0.007	LNRATIOPCHC(-6)	-3.391 ***	0.961
WP699(-34)	0.066 ***	0.006	LNRATIOPCHC(-7)	-3.306 ***	0.921
WP699(-35)	0.052 ***	0.005	LNRATIOPCHC(-8)	-2.712 ***	0.751
WP699(-36)	0.037 ***	0.003	LNRATIOPCHC(-9)	-1.610 ***	0.444
WP699(-37)	0.019 ***	0.002	H1DAY(-2)	-1.65	4.814
WP799(-10)	0.020 ***	0.002	H1DAY(-1)	-12.757 **	6.093
WP799(-11)	0.039 ***	0.004	H1DAY	-45.152 ***	6.320
WP799(-12)	0.055 ***	0.006	H1DAY(1)	-7.419	6.106
WP799(-13)	0.069 ***	0.007	H1DAY(2)	-6.348	4.938
WP799(-14)	0.081 ***	0.009	H2DAY(-2)	-5.868	9.269
WP799(-15)	0.091 ***	0.010	H2DAY(-1)	-53.567 ***	10.692
WP799(-16)	0.100 ***	0.011	H2DAY	-105.358 ***	10.969
WP799(-17)	0.106 ***	0.011	H2DAY(1)	0.879	10.679
WP799(-18)	0.110 ***	0.012	H2DAY(2)	-13.33	9.513
WP799(-19)	0.112 ***	0.012	RHO	0.460 ***	0.041
WP799(-20)	0.112 ***	0.012			

(*Note:* Single asterisks denote significance at the 10% level; double asterisks denote significance at the 5% level; and triple asterisks denote significance at 1% level)

Appendix C (2): 2nd -order polynomial function of estimated coefficients for four classes of placement by using “WP” data.



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