RELATIONSHIP BETWEEN CASTRATION AND MORBIDITY AND THEIR EFFECTS ON PERFORMANCE AND CARCASS QUALITY

by

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Abstract

When purchasing feeder calves, bulls are typically discounted relative to steers. Most would agree that a discount is warranted but determining the appropriate discount to apply is considerably more difficult. Being able to calculate this discount under varying conditions would help stocker operators maintain a certain level of profitability or recognize opportunities to make more profit when excessive discounts are being applied.

The goals of this study were to determine how castration timing affects performance (as measured by average daily gain), morbidity, and carcass quality and how morbidity affects performance and carcass quality. Ordinary Least Squares regression and logit models were estimated to quantify the effects of various management and environmental factors on performance, morbidity, and carcass quality. These model estimates of production variables along with price and cost assumptions were used to calculate breakeven purchase prices and price discounts for bulls relative to steers, accounting for the possibility of contracting bovine respiratory disease, if owned for a short backgrounding period or if ownership is retained through slaughter.

Model results confirm that late-castrated steers do indeed exhibit diminished performance and increased morbidity probabilities relative to early-castrated steers. Increased morbidity also decreases average daily gain. However, this study found that castration timing and morbidity during the backgrounding period have minimal effects on carcass quality, with morbidity only impacting hot carcass weight and castration timing significantly affecting days to market and only tending to impact hot carcass weight.

Ultimately, based on 2009 market conditions, bulls should be discounted at feeder calf sales compared to steers. The average calf arrived at 459 pounds, and at this weight bulls should

be discounted $4.69/cwt relative to the same weight steers. The discount increases to $5.37/cwt for 400 pound calves and drops to $4.20/cwt for 500 pound calves. If ownership is retained through slaughter, required discounts will change to $6.77/cwt, $4.91/cwt, and $7.55/cwt, respectively.

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CHAPTER 1 - INTRODUCTION

1.1 Background Information

Cattle backgrounding operators have several considerations when making production decisions. Backgrounding is the production phase between weaning and the feedlot. The purchase price of feeder calves is one of the main costs of production, thus it has a large impact on profitability. Purchase price has much variability depending primarily on cattle characteristics and time of sale, so the main question buyers should be asking is "How much can I pay for cattle and breakeven or make a predetermined amount of profit per head?" Clearly several factors would be involved in this calculation, such as breed, health status, and castration status, in which castration timing is the main focus of this thesis.

The process of castration affects profitability as it is stressful to bulls, which directly lowers average daily gain (ADG) and indirectly increases the animals' susceptibility to bovine respiratory disease (BRD) (Ratcliff et al., 2005). Therefore, it is important to determine just how castration timing, i.e., prior to or after purchase, affects gain. Dependent upon management practices, lost gain would result in lighter animals at sale to a feedlot or more days on feed before sale to a feedlot. Diminished gain due to castration can also be compounded by the effects of illness, most importantly BRD. Bovine respiratory disease is considered to be the primary disease problem of recently weaned and/or received calves and is the most common disease of feedlot cattle (Speer, Young, and Roeber, 2001). Not only does BRD result directly in lost profits at sale because of selling at lighter weights or increased costs due to more days on feed, but also labor, medication and veterinarian costs would increase due to monitoring and treating morbid cattle.

BRD is such a prevalent problem within the feedlot cattle population that many producers engage in metaphylaxis treatment, i.e., mass treatment, upon arrival via vaccines or antibiotics. Several drugs are currently on the market for metaphylaxis treatment of BRD, each with different costs and efficacies. Various trials testing these drugs report a 20-44% reduction in sickness rate and a 0-24% reduction in death loss. Veterinarians should consider age and source of cattle, stress the cattle will endure, and previous laboratory antibiotic sensitivities for isolated bacterial pathogens when making an antibiotic selection (Griffin, 2006). Therefore, this study secondarily examines three metaphylaxis drugs and how they affect performance and morbidity as will be done with timing of castration.

The sole purpose of growing feeder calves is to sell to feedlots who in turn sell the cattle to packers for slaughter. Feedlot returns are based on fed price level, a function of carcass quality, and cost of gain which is a result of genetics and all production decisions administered throughout an animal's life, from the cow/calf producer to the backgrounder to the feedlot operator. Again, the main focus of this research is to examine the effects of castration timing relative to arrival at a stocker operation and how castration affects morbidity. It is presumed that due to biological differences of bulls and steers that early- and late-castrated steers may consistently have carcasses of differing quality. Furthermore, morbidity may also affect carcass quality. Though there typically is no direct effect on cow/calf producers or backgrounders from varying carcass quality and value, unless retained ownership is involved, it is still important to consider carcass quality implications. A "trickle-down" effect should occur within the cattle marketing structure. Packers reward feedlots for high-quality carcasses and discount for problem carcasses. Feedlots, in turn, should seek out and be able to pay more for consistent high-quality cattle and less for those resulting in lower quality carcasses. Therefore, backgrounders are able to pay more for those that should ultimately result in better carcasses or discount those that are more likely to result in discounted carcasses.

The implications of this research are relevant to backgrounding operators as purchase prices affect the financial bottom line. Determining how much less a calf is worth at purchase, due to its characteristics, such as castration and health status, affects direct costs of production and can help improve profitability. If markets are efficient, then the discounts found in this study will be similar to actual market price differentials. Biologically, healthy calves are more feed efficient, that is they require less pounds of feed per pound of gain, and they obtain their target weight more rapidly. Economically, this translates into healthy calves having lower feed costs and resulting in greater turnover in the feedlot.

1.2 Research Objectives

To reiterate, the main focus of this thesis is on the effects of the timing of castration of beef cattle on subsequent performance and health. Secondarily, three metaphylaxis treatments are examined for their effects on performance and health. Finally, the effects of castration status and morbidity on carcass quality are studied. In clarifying some terminology used throughout this research, "early-castrated steers" refers to bulls that had already been castrated at purchase. Bulls that were purchased and subsequently castrated on arrival are interchangeably referred to as "newly-castrated steers" or "late-castrated steers." Explicitly, the objectives of this study are:

1. To determine what effects castration timing has on:
    a. performance as measured by average daily gain, and if differences between early- and late-castrated steers are found to exist, analyze their economic impacts,

b. morbidity as indicated by number of BRD treatments, and if differences between early- and late-castrated steers are found to exist, analyze their economic impacts, and
c. carcass quality, and if differences between early- and late-castrated steers are found to exist, analyze their economic impacts.

2. To determine what effects BRD morbidity have on:
   a. performance as measured by average daily gain, and if differences between morbid and non-morbid stocker calves are found to exist, analyze their economic impacts, and
   b. carcass quality, and if differences between morbid and non-morbid stocker calves are found to exist, analyze their economic impacts.
3. To determine what effects three metaphylaxis treatments have on:
   a. performance as measured by average daily gain, and if differences between cattle treated with the different drugs are found to exist, analyze their economic impacts, and
   b. morbidity as indicated by number of BRD treatments, and if differences between cattle treated with the different drugs are found to exist, analyze their economic impacts.

Mortality is an entirely separate issue from morbidity and clearly has detrimental effects on profitability. However, even though there was a difference in mortality rates between steers (0.85%) and bulls (2.81%), because the overall mortality rate for the data used in this research is quite low (2.1%), thoughts of examining, determining, and analyzing factors affecting mortality were abandoned at the onset.

It is important to note that this study focuses on the implications of production and management decisions in the stockering phase, however, the data available comes from receiving trials and covers a smaller timeframe than true backgrounding operations, thus results from these receiving trials would need to be extrapolated for the extended backgrounding phase.

1.3 Thesis Organization

This thesis is organized into seven chapters. Chapter 2 reviews the relevant literature pertaining to bulls, steers, castration and bovine respiratory disease and their effects on morbidity incidence and carcass quality. Chapter 3 then details the data involved in this study. The next three chapters separate the three main objectives into three areas of analysis: performance, morbidity, and carcass quality. Within each chapter, the models estimated and ensuing results are presented. The performance and morbidity models examining metaphylaxis treatment closely resemble the performance and morbidity models analyzing castration timing and thus are paired together, with the information on castration timing always preceding the information on metaphylaxis treatment. These results are then followed with both statistical and economic analyses. Finally, concluding remarks are presented in Chapter 7.

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

The purpose of this literature review is to summarize the results of various studies throughout the years that analyzed the performance, morbidity, and carcass quality differences between bulls and steers, early- and late-castrated steers and cattle treated or not treated for bovine respiratory disease (BRD). Much research has been done on the economic viability of raising and slaughtering intact versus castrated males, as well as the effects of the method and timing of different castration techniques. Furthermore, BRD is the most common disease of feedlot cattle (Speer, Young, and Roeber, 2001), and considerable research has been conducted on most aspects of BRD including causative agents, preventative measures, incidence rates, and effects on performance and carcass quality.

This chapter first briefly reviews the advantages and disadvantages of feeding out bulls compared to steers. It then turns to examine castration and how it affects performance and BRD incidence, followed by castration's effect on carcass quality. The chapter ends with a review of BRD, split into two sections, first looking at BRD's effects on performance and morbidity incidence and then analyzing its effects on carcass quality. The results of these previous studies will then be compared to the results of this study in the concluding chapter.

2.2 Bulls and Steers: Performance and Carcass Quality Effects

Throughout the years, several researchers have studied whether it is more economical to feed and finish steers or bulls. Though some research continues to be done in this area, most have found that the problems and costs of raising bulls outweigh the costs of castrating them;

therefore, it is better to feed out steers rather than intact bulls. Seideman et al. (1982) and Field (1971) both cite various studies where bulls have consistently demonstrated greater feed efficiency than steers. Bulls required less feed per pound of gain as well as gained weight faster. Additionally, most studies show that bulls produce leaner carcasses while maintaining similar dressing percentages. Research (Champagne et al., 1969; Field, 1971; Landon, Hedrick, and Thompson, 1978; Gregory and Ford, 1983) consistently finds that bulls have less external fat. Both Gregory and Ford (1983) and Champagne et al. (1969) determined that bull carcasses exhibited less marbling, which concurs with findings by Landon, Hedrick, and Thompson (1978) that bulls grade lower than steers. Furthermore, Gregory and Ford (1983) also determined that bulls had significantly higher hot carcass weights, while bull carcasses in the Champagne et al. study (1969) exhibited a trend toward a larger longissimus area with increasing age at castration.

Seideman et al. (1982) continued their analysis by outlining the disadvantages of feeding out bulls. Bull hides are often thicker, thus more difficult to remove. Dark cutting meat is more often associated with bulls; coarse muscle texture often accompanies the darker appearance. Bull carcasses are more often of lower USDA quality grades. Leaner carcasses were stated as an advantage; however, less intramuscular fat is usually associated with leaner carcasses and therefore results in the lower quality grades. Finally, though bulls gain faster, steers are more likely to attain the optimum fat endpoint sooner than bulls, ultimately resulting in fewer days on feed. This extra time on feed can also mean large carcass weights for bulls that will be discounted.

Schoonmaker et al. (2002) studied how age at feedlot entry affected performance and carcass characteristics of bulls and steers. They found that there is a viable management option of feeding bulls in an early-weaned system. However, as the entry age of bulls increases, they found that intramuscular fat deposition is increasingly impeded, and the potential for overweight carcasses increases. Overall, bulls have been found to have less marbling, less subcutaneous fat, more longissimus area, less kidney fat and lower USDA quality grades than steers (Seideman et al., 1982).

All these disadvantages are in addition to the greater temperamental problems associated with bulls. Bulls can be more difficult and dangerous to handle and process; they are also harder on equipment and fences, increasing wear and tear. It is for these various reasons that feedlots prefer steers to bulls and why this study focuses on the timing of castration rather than the question of whether or not to castrate.

2.3 Castration Timing

2.3.1 Performance and Morbidity Effects

The method and timing of castration has also been frequently researched and studied over the last half century. The first results to discuss are the average daily gain (ADG) results of Wierbicki et al. (1955). In three different experimental trials, late-castrated steers (castrated three to seven months after the first group) had no difference in ADG, gained 0.02 pounds less per day, and gained 0.23 pounds less per day when compared to the performance of early-castrated bulls. To reaffirm the previous section, intact bulls in each group gained 0.23-0.47 pounds per day more than all steer groups.

Duff and Galyean (2007) discuss the effects of castration in the course of analyzing management practices of highly stressed, newly received feedlot cattle. Castration is clearly a stress factor for intact bulls and is often performed at or very near arrival along with other processing stresses such as vaccination and dehorning. Duff and Galyean review other studies.

In one, bulls castrated on arrival had a 92% greater incidence of morbidity and a 3.5% higher mortality rate compared with their counterparts that had been castrated prior to arrival. Additionally, these previously castrated calves were found to gain 0.31 kg/day more during a 21-day receiving trial than those castrated at arrival. Another study found that "as the age of castration gets closer to birth, less weight is lost for the 30-d period after castration" (Duff and Galyean, 2007, p. 828). The third study reviewed found that when castration was performed at more than six months of age, body weight gain at weaning was decreased for at least 30 days.

Lents et al. (2006) ran two different experiments to determine the effects of method of castration and age at which castration occurs on body weight gain of bulls before and after weaning. In the first experiment, bull calves were castrated at 2 to 3 months of age or at weaning (7 to 8 months). In the second experiment, bulls were banded within 2 days after birth or 30 days prior to weaning (at 208 ± 3 days). Late-castrated steers had decreased gains during the 50 days following weaning/castration while those castrated 30 days prior to weaning had reduced gains for just the 30 days following castration. Though the stress of weaning probably contributed to the diminished gains of the late-castrated steers in experiment one, the decreased gains of the late-castrated steers in experiment two indicate that late-castration alone can reduce body weight gain. Growth rates were not impeded for the bulls castrated at younger ages.

Berry et al. (2001) and Ratcliff et al. (2005) both studied the method of castration and the differences between those arriving at receiving units as steers or as bulls. Neither study found an effect for castration method on morbidity, but Berry et al. found that banding intact males decreased ADG more than surgical castration. Both studies found that steers had higher ADG than newly-castrated steers, 0.58 lbs/day and 0.50 lbs/day, respectively, and that steers had overall less morbidity. Ratcliff et al. found an even greater difference in ADG, 1.94 lbs/day, between steers and newly-castrated steers in the first seven days post arrival. They also reported that 29% more bulls were treated for respiratory disease than steers. Additionally, nearly 15% more bulls required a second treatment.

2.3.2 Carcass Quality Effects

Most castration research comparing carcass quality in male cattle concentrates on castrating or not, i.e., bulls versus steers, rather than the timing of castration. However, some studies look at early- compared to late-castration or various methods and timing of castration in addition to leaving one or more groups intact.

In Landon, Hedrick, and Thompson's study (1978), the experimental groups consisted of bulls castrated at birth, bulls castrated at 205 days, and bullocks. They observed significant differences in quality grades among these groups; all bullock groups graded worse than all steer groups, and the bulls castrated at birth had the most marbling of any group. These results are further supported by Champagne et al. (1969), which also found that the closer to birth a bull is castrated, the more marbling is found in the carcass, thus those carcasses are graded higher. Additionally, Worrell, Clanton, and Calkins (1987) found that bulls surgically castrated at less than 230 kg had increased marbling scores and tenderness compared with those castrated between 320 and 410 kg. In contrast, Lents et al. (2006) found that even though ADG was reduced in bulls that were castrated at 6 to 7 months of age, there were no negative effects of late castration on the measured carcass traits (as compared to those banded within two days of birth). Furthermore, Klosterman et al. (1954) did not find any significant differences in any carcass traits between steers castrated at birth or those castrated at weaning.

2.4 Bovine Respiratory Disease

2.4.1 Performance Effects

In addition to the direct loss of weight gain due to castration, it is presumed, based on results of other studies, that newly-castrated steers are more susceptible to disease, bovine respiratory disease (BRD) in particular. BRD is the most common disease of feedlot cattle, responsible for about 75% of total morbidity cases, and is considered to be the primary disease problem of recently weaned and/or received calves. The highest incidence of BRD usually occurs within the first 45 days of arrival, and BRD is the cause of approximately 45-55% of all feedyard deaths. Additionally, BRD morbidity rates are highly correlated with both mortality rates and treatment costs, resulting in about 8% of total production costs excluding losses related to reduced performance (Speer, Young, and Roeber, 2001). In a study of feedlot cattle by Schneider et al. (2009), there was an incidence rate of BRD of 8.17%. Of this percentage treated for BRD, 53% were treated once, 34% twice, and 13% three or more times. Additionally, the average day of first treatment was 40 days after entering the feedlot, and 75% of treated cattle had been treated by day 55.

Most studies report that “healthy” cattle have higher daily gains (from 0.04-0.25 kg/day); however, some research reports no significant differences between the ADG of those not treated for BRD compared to those that had been treated (Gardner et al., 1999; Stovall et al., 2000). Gardner et al. (1999) reported that final weights did not differ between steers treated once versus more than once, but those treated only once did gain 0.14 kg/day faster. They also stated their results were supported by another study in which calves treated more than once for BRD had 0.49 kg/day lower ADG than those treated only once.

2.4.2 Carcass Quality Effects

Due to the sheer magnitude of this disease, many researchers have studied how BRD affects the economics of the entire cattle industry in addition to performance and carcass characteristics. Almost all studies report that cattle treated for disease produce carcasses with lower marbling scores and lower U.S. Department of Agriculture (USDA) quality grades (Gardner et al., 1999; Stovall et al., 2000; Speer, Young, and Roeber, 2001; Schneider et al., 2009).

Specifically, Schneider et al. (2009) found that both the incidence of BRD and the number of treatments described a significant amount of variation in hot carcass weight (HCW), subcutaneous fat cover (backfat), and marbling score. Untreated cattle had more desirable carcass trait estimates compared with treated cattle, and as the number of BRD treatments increased, HCW and marbling score decreased. More than 70% of untreated calves graded Choice or better, whereas, those treated at least once graded Choice or better less than 60% of the time. Stovall et al. (2000) reported similar results. Heifers that received multiple treatments had lower HCW, and treated heifers also tended to have lower yield grades. Additionally, heifers receiving two or more treatments for BRD also had significantly lower marbling scores, with a 25% reduction in the percentage of carcasses grading Choice or better for heifers being treated multiple times.

Gardner et al. (1999) also studied the carcass quality differences between steers treated and not treated for BRD. Untreated steers had heavier carcass weights than treated steers, and those treated only once had heavier carcass weights than those treated multiple times. Subcutaneous fat measurements yielded the same results as HCW; treated steers were fatter than untreated steers, and steers treated once were fatter than steers treated more than once. Where untreated calves tended to have larger longissimus muscle areas (ribeye areas) than treated steers, no significant difference existed in terms of number of treatments. Both treated steers and those treated multiple times tended to have slightly lower marbling scores than those never treated and those treated just once, as well. Therefore, untreated steers resulted in carcasses with better yield and quality grades than treated steers, and steers treated just once had carcasses with better yield and quality grades than steers treated more than once.

The detrimental effects of disease on performance and carcass characteristics ultimately affect returns. Speer, Young, and Roeber (2001) found that “healthy” cattle in a six-year summary of the Texas A&M Ranch to Rail program returned over $95 more per head than those categorized as “sick.” Stovall et al. (2000) found that heifers that were treated once or more netted $11.48 and $37.34 per head less, respectively, than heifers not treated.

CHAPTER 3 - MODEL DATA

The primary data for this study comes from the Kansas State University (K-State) Beef Stocker Unit. Originally called the K-State Animal Science Range Unit, the Beef Stocker Unit was refocused in 2004 to provide an avenue for backgrounding and stocker cattle research. A new facility consisting of 24 receiving pens designed to hold 300 head of 500 pound cattle was built in 2005. This new facility allowed the unit to begin new research on receiving cattle (Beef Stocker Unit).

Information such as arrival date, identification number, sex, starting weight, revaccination weight, ending weight, lot, season, source, morbidity status, mortality status, and metaphylaxis treatment were recorded on 3,380 male calves in 11 receiving trials from March 2006 to October 2008. Each trial was composed of three lots (or loads). Each lot consisted of approximately 100 head. Lots were not commingled, but each lot was randomly separated into eight different pens with bulls and steers being evenly distributed among the pens.

Immediately after being unloaded, Day 0, the calves were weighed, new ID tagged and palpated to determine sex, i.e., steer or bull; all this information was used to randomize calves into different pens the following day. The next morning all calves are administered clostridial vaccinations; respiratory vaccinations for IBR, BVD Types I and II, PI3 and BRSV; antibiotic metaphylaxis treatment; and wormer, and bulls are surgically castrated. They were then sorted into pen groups out of the chute. Cattle arriving with horns were not dehorned. The K-State Beef Stocker Unit feels that the dehorning variable needs to be randomized between all pens and treatments similar to how castration is. Since there are usually less than eight head/load that have horns that need to be shortened, they do not dehorn and thus bypass this variable (Epp, 2009). All lots were revaccinated with the clostridial and respiratory vaccines; most lots were revaccinated 12-16 days after initial vaccination. The day from arrival was recorded for each revaccination and ending weight; all weights were taken in the morning before a full day on feed. Due to study protocols, there was a range of days on feed (DOF) until both the revaccination and ending weights. Additionally, one trial was on a limit-feed diet for 45 days post-revaccination. All other cattle had ad libitum access to feed, i.e., access to feed all day, every day.

One of three metaphylaxis treatments were administered to all cattle: Draxxin (Pfizer, New York, NY), Micotil (Elanco, Greenfield, IN) or Excede (Pfizer, New York, NY). Metaphylaxis treatment is mass medical treatment administered to a group of animals in the attempt to eliminate or reduce the incidence of an expected disease. There were only two receiving trials that varied which treatment was administered; half were administered Draxxin, and the other half, Micotil. Only a single metaphylaxis treatment was administered to all animals within the other trials.

At the conclusion of each trial, each animal was assigned a morbidity status of 0-4; 0 indicated no treatment for anything, 1 for those that were treated for bovine respiratory disease (BRD) once, 2 for those that were treated for BRD twice, 3 for those that were treated for BRD three times, and 4 designated those that were treated for something other than BRD such as foot rot or pinkeye. Cattle were treated for BRD only if their temperatures were at least 104°F.

The source of each lot (or load) was identified as one of the following: Dickson, TN; Waynesboro, TN; Guthrie, KY; Sweetwater, TN and additional pick-ups; and Glasgow, KY. The arrival seasons identified were spring (February-April), early summer (May and June), late summer (July-September), and fall (October and November).

Carcass data were collected on a random set of calves across two different trials (or six loads/lots). Hays Feeders fed out the cattle, which were sonogrammed to determine preliminary carcass characteristics and to decide whether cattle were ready for slaughter or not. U.S. Premium Beef slaughtered the calves and collected the carcass information. The data collected included kill date, hot carcass weight (HCW), quality grade, yield grade, marbling score, ribeye area (REA), backfat (BF), price per head and price per hundredweight (cwt), as well as whether or not a carcass qualified for Certified Angus Beef (CAB) or NAB, a U.S. Premium Beef in-house grade (no additional information regarding NAB was available), or if it showed one of the following discount characteristics: hard bone, dark cutter, or age of thirty months.

CHAPTER 4 - PERFORMANCE

4.1 Modeling

Performance of the cattle is evaluated via average daily gains. Two different time periods were examined, from arrival until revaccination and from arrival until shipment. Average daily gain from arrival to shipment is abbreviated as ADG, and average daily gain from arrival to revaccination is indicated by RADG. These two gains were calculated as follows:

(4.1) $$ADG = \frac{ending\ weight - starting\ weight}{DOF}$$

(4.2) $$RADG = \frac{revaccination\ weight - starting\ weight}{RDOF},$$

where DOF is the days on feed for the entire period, and RDOF is the days on feed prior to revaccination. All of the daily gain models reported in the chapter were estimated in SAS utilizing ordinary least squares (OLS).

4.1.1 Castration Timing

Performance of cattle is determined by a variety of factors such as genetics, breed, sex, management practices, environmental factors, nutritional availability, and health. However, not all this information was readily available, so it was determined that the conceptual model would be as follows to attempt to explain as much of the variability in performance as possible:

(4.3) $$ADG = f\begin{pmatrix} sex, starting\ weight, arrival\ season, arrival\ year, \\ source, morbidity\ status, situational\ considerations \end{pmatrix}$$

where the variables for this model and all the other conceptual and empirical models are described in Table 4.1, and all possibilities of discrete variables such as arrival seasons, arrival years, and sources are included in the model unless otherwise indicated. For example, in one of the models cattle may only have arrived in spring and early summer instead of in all four possible seasons, and this will be noted in the model. Situational considerations would include explanatory factors specific to a group of cattle (or situation) such as feed access, for Equation 4.4 and metaphylaxis treatment, for other models such as Equation 4.6. Summary statistics for the dataset are reported in Table 4.2. Sixty-five percent of calves arrived as bulls. Average daily gain for the entire dataset 3.1 pounds with steers at 3.4 pounds and bulls at 2.9 pounds. These gains are higher than what typically might be expected in a cattle receiving period. All weights used are actual shrunk weights as weighed and recorded by the K-State Stocker Unit; therefore cattle are able to exhibit greater than expected gains. Ensuing results were checked for sensitivity to shrink, and results were generally quite robust. Twenty-eight percent of calves required treatment for BRD; 40% of those treated for BRD required multiple BRD treatments. Correlation coefficients of explanatory variables are reported in Table 4.3. As expected, the variables with the highest correlation coefficients are those between the weight and gain variables. Additionally, morbidity was somewhat highly correlated with both RADG and ADG with coefficients of -0.356 and -0.400, respectively, which indicates that the more times a calf is treated for BRD the lower are his average daily gains.

Table 4.1 Variable Descriptions

Variable	Description
Sex	Binary variable equal to 0 if a steer, 1 if a bull
StartWt	Starting (initial) weight of the animal (pounds)
*Sex*StWt*	Interaction term of *Sex*StartWt*
ReVaccWt	Weight of the animal at revaccination (pounds)
EndWt	Ending weight of the animal (pounds)
RADG	Average daily gain from arrival through revaccination
ADG	Average daily gain from arrival through shipment
Feed	Binary variable equal to 1 if on limit-feed diet, 0 ad libitum access
MorbidityYes	Binary variable equal to 1 if treated for BRD, 0 if not treated for BRD
Arrival Season	
Season0	Binary variable equal to 1 if arrived in spring, 0 otherwise
Season1	Binary variable equal to 1 if arrived in early summer, 0 otherwise
Season2	Binary variable equal to 1 if arrived in late summer, 0 otherwise
Season3	Binary variable equal to 1 if arrived in fall, 0 otherwise
Arrival Year	
Year06	Binary variable equal to 1 if arrived in 2006, 0 otherwise
Year07	Binary variable equal to 1 if arrived in 2007, 0 otherwise
Year08	Binary variable equal to 1 if arrived in 2008, 0 otherwise
Source	
Source0	Binary variable equal to 1 if from Dickson, TN, 0 otherwise
Source1	Binary variable equal to 1 if from Waynesboro, TN, 0 otherwise
Source2	Binary variable equal to 1 if from Guthrie, KY, 0 otherwise
Source3	Binary variable equal to 1 if from Sweetwater, TN + additional pickups, 0 otherwise
Source4	Binary variable equal to 1 if from Glasgow, KY, 0 otherwise
Morbidity	Discrete variable equal to 0 if never treated for BRD, 1 if treated for BRD once, 2 if treated for BRD twice, 3 if treated for BRD three times
Morbidity0	Binary variable equal to 1 if never treated, 0 otherwise
Morbidity1	Binary variable equal to 1 if treated once for BRD, 0 otherwise
Morbidity2	Binary variable equal to 1 if treated twice for BRD, 0 otherwise
Morbidity3	Binary variable equal to 1 if treated three times for BRD, 0 otherwise
Morbidity4	Binary variable equal to 1 if treated for something other than BRD, 0 otherwise

Table 4.1 Continued

Variable	Description
Metaphylaxis Treatment	
Metaphyl0	Binary variable equal to 1 if treated with Draxxin, 0 otherwise
Metaphyl1	Binary variable equal to 1 if treated with Micotil, 0 otherwise
Metaphyl2	Binary variable equal to 1 if treated with Excede, 0 otherwise
Metaphylaxis*Sex	
*Meta0*Sex*	Interaction term equal to *Metaphyl0*Sex*; binary variable equal to 1 if a bull treated with Draxxin, 0 otherwise
*Meta1*Sex*	Interaction term equal to *Metaphyl1*Sex*; binary variable equal to 1 if a bull treated with Micotil, 0 otherwise
*Meta2*Sex*	Interaction term equal to *Metaphyl2*Sex*; binary variable equal to 1 if a bull treated with Excede, 0 otherwise
Carcass Characteristics	
HCW	Hot carcass weight (pounds)
HCW2	Hot carcass weight squared
REA	Ribeye area (square inches)
BF	Backfat (inches)
YieldGrade	Discrete variable equal to 1 if YG1, 2 if YG2, 3 if YG3 and 4 if YG4
MarblingScore	Marbling score assigned to carcass[†]
ChoicePlus	Binary variable equal to 1 if USDA Choice quality grade or better, 0 otherwise
DaysToMkt	Number of days to market, i.e., from arrival at stocker unit until slaughter
CAB	Binary variable equal to 1 if qualified for CAB, 0 otherwise
NAB	Binary variable equal to 1 if qualified for NAB, 0 otherwise
Discounts	Binary variable equal to 1 if exhibited discount characteristic (hard bone, dark cutter, age 30 months), 0 otherwise
PriceCWT	Carcass price per hundredweight
Quality Grade	
QualityGrade1	Binary variable equal to 1 if Standard, 0 otherwise
QualityGrade2	Binary variable equal to 1 if Select, 0 otherwise
QualityGrade3	Binary variable equal to 1 if Choice, 0 otherwise
QualityGrade4	Binary variable equal to 1 if Prime, 0 otherwise

[†]*MarblingScores* reported as Traces 100, Slight 200, Small 300, Modest 400, Moderate 500, Slightly Abundant 600

Table 4.2 Summary Statistics for Dataset

Variable	Mean	Standard Deviation	Min	Max	Frequency	Percentage
StartWt (All)	**458.8**	**41.9**	**318**	**642**	**3380**	**100%**
StartWt (Steers)	462.6	45.3	318	642	1177	35%
StartWt (Bulls)	456.7	39.9	318	596	2203	65%
ReVaccWt (All)	**516.2**	**53.2**	**338**	**758**	**3342**	**100%**
ReVaccWt (Steers)	528.7	56.9	356	758	1174	35%
ReVaccWt (Bulls)	509.4	49.8	338	678	2168	65%
RADG (All)	**4.4**	**2.3**	**-6.4**	**19.6**	**3342**	**100%**
RADG (Steers)	4.9	2.3	-3.1	19.6	1174	35%
RADG (Bulls)	4.0	2.2	-6.4	14.3	2168	65%
EndWt (All)	**593.1**	**60.2**	**348**	**854**	**3302**	**100%**
EndWt (Steers)	608.0	62.6	388	854	1165	35%
EndWt (Bulls)	585.1	57.2	348	778	2137	65%
ADG (All)	**3.1**	**1.0**	**-2.7**	**7.6**	**3302**	**100%**
ADG (Steers)	3.4	1.0	-2.7	7.6	1165	35%
ADG (Bulls)	2.9	1.0	-2.5	6.1	2137	65%
Sex						
Steers (Sex = 0)					1177	35%
Bulls (Sex = 1)					2203	65%
Feed						
Ad Libitum (Feed = 0)					3046	90%
Limit Feed (Feed = 1)					334	10%
Arrival Season						
Season0					954	28%
Season1					916	27%
Season2					602	18%
Season3					908	27%
Arrival Year						
Year06					892	26%
Year07					1245	37%
Year08					1243	37%
Source						
Source0					1441	43%
Source1					713	21%
Source2					104	3%
Source3					1020	30%
Source4					102	3%
Morbidity						
Morbidity0					2415	71%
Morbidity1					559	17%
Morbidity2					260	8%
Morbidity3					113	3%
Morbidity4					33	1%
MorbidityYes						
Not treated for BRD (MorbidityYes=0)					2448	72%
Treated for BRD (MorbidityYes=1)					932	28%

Number of observations = 3380

Table 4.3 Correlation Coefficients of Performance Model Variables

Variable	*Sex*	*StartWt*	*ReVaccWt*	*RADG*	*EndWt*	*ADG*	*Morbidity*†
Sex	–						
StartWt	-0.067	–					
ReVaccWt	-0.173	0.814	–				
RADG	-0.184	0.008	0.428	–			
EndWt	-0.182	0.671	0.801	0.518	–		
ADG	-0.203	0.057	0.401	0.685	0.722	–	
Morbidity†	0.081	0.004	-0.160	-0.356	-0.308	-0.400	–

†*Morbidity* is a discrete variable equal to 0 if never treated for BRD, 1 if treated for BRD once, 2 if treated for BRD twice, 3 if treated for BRD three times.

From the conceptual model, the empirical model estimated is the following:

$$(4.4) \quad ADG = \alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s \, Season_s + \sum_{y=6}^{7} \beta_y \, Year_y + \sum_{r=8}^{11} \beta_r \, Source_r + \sum_{m=12}^{16} \beta_m \, Morbidity_m + \beta_{17} Feed,$$

where

Season$_s$ = a set of dummy variables for arrival season (*s* = spring, early summer, late summer, fall; default = spring)

Year$_y$ = a set of dummy variables for arrival season (*y* = 2006, 2007, 2008; default = 2006)

Source$_r$ = a set of dummy variables for lot source (*r* = Dickson, TN; Waynesboro, TN; Guthrie, KY; Sweetwater, TN and additional pick-ups; Glasgow, KY; default = Dickson, TN)

Morbidity$_m$ = a set of dummy variables for morbidity (*m* = 0 if never treated, 1 if treated once for BRD, 2 if treated twice for BRD, 3 if treated three times for BRD, 4 if treated for something other than BRD; default = 0).

Since bulls are castrated upon arrival, thus undergoing more stress than steers, the coefficient on the sex variable is expected to be negative since the variable is defined as steer =

0, bull = 1. The starting weight variable is expected to be negatively correlated with ADG because feed conversion and average daily gain typically get worse with age, as indicated by weight since age is unknown (Gill, Barnes, and Lalman). The expectation of the signs of the season variables are somewhat ambiguous, but it is expected that ADG would be less in the hotter summer months. Expected signs on arrival year are also ambiguous. Since all the cattle came from the same region, Kentucky and Tennessee, there are no expectations for the signs of the source variables. The expected signs and relative magnitudes of the coefficients on the morbidity variables are intuitive. Cattle that are treated should have a lower ADG than those that are not, i.e., negative coefficients. Those that are treated more often should have even lower ADG, i.e., larger negative coefficients. Per the definition of the feed dummy variable (ad libitum access = 0, on limit-feed diet = 1), the coefficient is expected to be negative as those on full feed should gain more.

The second empirical model estimated is the following:

$$(4.5)\quad RADG = \alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \sum_{m=12}^{16} \beta_m\, Morbidity_m$$

where all variables are the same as defined in Equation 4.4.

The same signs would be expected for the coefficients, however, magnitude of some coefficients and significance would be expected to vary from the first model. The magnitude of the sex coefficient should be larger in this equation as castration is a stressor that is most significantly felt nearest the time of processing. Newly-castrated steers would have time over the entire trial to compensate some for the weight lost during this time. Furthermore, some of the morbidity variables may be insignificant for this model. Time from arrival to BRD treatment was not examined in this study, but as mentioned previously, another study found that 40 days was the average for first treatment and that 75% of calves were treated in the first 55 days (Schneider et al., 2009). Therefore, since the average days to revaccination is only 14 days, some cattle will have yet to be treated for the first time and others yet to be treated more than once. Finally, the limit-feed diet did not begin until after revaccination, so the feed dummy variable was not included.

4.1.2 Metaphylaxis Treatment

The study next looked at the effects of the different metaphylaxis treatments on ADG. The first model looks at ADG for the entire period while the subsequent model looks at ADG from arrival to revaccination. Again, this model is attempting to analyze performance, only this time also looking at the effects of metaphylaxis treatment on performance, therefore the conceptual model would be identical to the first one (Equation 4.3). Therefore the first empirical model is as follows:

$$(4.6)\quad ADG = \alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \sum_{m=12}^{16} \beta_m\, Morbidity_m + \beta_{17} Feed + \sum_{p=18}^{19} Metaphyl_p + \sum_{p=20}^{21} Meta_p * Sex,$$

where

Metaphyl$_p$= a set of dummy variables for metaphylaxis treatment (*p* = Draxxin, Micotil, Excede)

Meta$_p$**Sex* = a set of interaction dummy variables for metaphylaxis treatment*sex (*p* = Draxxin, Micotil, Excede) and all other variables are as previously defined in Equation 4.4 and Table 4.1. Summary statistics for the metaphylaxis dummy variables and metaphylaxis, sex interaction variables are presented in Table 4.4.

Table 4.4 Summary Statistics for Metaphylaxis Treatment

Variable	Mean	Standard Deviation	Min	Max	Frequency	Percentage
Metaphylaxis (All)						
Draxxin (Metaphyl0 = 1)					2465	73%
Micotil (Metaphyl1 = 1)					297	9%
Excede (Metaphyl2 = 1)					618	18%
Metaphylaxis*Sex						
*Draxxin Steers (Meta0*Sex = 0)*					854	25%
*Draxxin Bulls (Meta0*Sex = 1)*					1611	48%
*Micotil Steers (Meta1*Sex = 0)*					113	3%
*Micotil Bulls (Meta1*Sex = 1)*					184	5%
*Excede Steers (Meta2*Sex = 0)*					210	6%
*Excede Bulls (Meta2*Sex = 1)*					408	12%

Number of observations = 3380

The expected signs on the coefficients would be the same as for those in Equation 4.4 for the same reasons; sex should be negative; weight, negative; season and source ambiguous; morbidities 1 through 4, negative; and feed, negative. The metaphylaxis dummy variables have been added. The expected signs are ambiguous; however, they are expected to be significant as one would surmise that the treatments will vary in efficacy for these specific receiving trials of cattle, thus metaphylaxis treatments should allow for increased ADG relative to each other. Treatment efficacy could vary from one group of cattle to another dependent upon environmental conditions outlined by Griffin (2006), such as age and source of cattle, stress exposure, and previous laboratory antibiotic sensitivities for isolated bacterial pathogens. It is for these reasons that interaction terms between metaphylaxis treatment and sex are included. If timing of castration does affect treatment efficacy, then the coefficients will be significant.

The next model analyzes performance from receiving to revaccination; therefore the conceptual model would be identical to the first conceptual model (Equation 4.3). The second empirical model is:

$$(4.7) \quad RADG = \alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \sum_{m=12}^{16} \beta_m\, Morbidity_m + \sum_{p=17}^{18} Metaphyl_p + \sum_{p=19}^{20} Meta_p * Sex.$$

where all independent variables are the same as in Equation 4.6.

For Equation 4.7, the expected signs and magnitudes of the coefficients would be the same as for those same variables in Equation 4.5. The metaphylaxis dummy variables should be significant in this equation, as well. The interaction terms will be significant if castration timing impacts treatment efficacy.

4.2 Statistical Analysis

4.2.1 Castration Timing

The estimated parameter coefficients for the ADG model (Equation 4.4) are shown in Table 4.5; the model explains 36% of the variability in ADG. Due to deathloss, the number of observations for model estimation is slightly less than the 3380 total observations. Nearly all of the variables are significant at the one percent level with the exception of the *Season3* and *Source4* variables which are significant at the five percent level and the *Season1* variable which is not statistically significant. A sex, starting weight interaction variable should be included and important in this model as castration is a stressor and even more so on heavier weight bulls. However, when the model including this interaction term was estimated, the sex and weight variables were not statistically significant. When the interaction term was dropped, both the sex and starting weight variables were statistically significant. Thus this interaction term was left out of all succeeding performance and morbidity models. Additionally, to allow for a nonlinear weight effect, a starting weight squared term could be included and important in the model as well. That is, ADG might increase over time but at a decreasing weight as cattle get heavier. Much like when the interaction term was included, the starting weight variables were not statistically significant when a squared term was included in the model. When the starting weight squared term was dropped, the starting weight variable again regained statistical significance and explanatory power. Thus, the starting weight squared term was also excluded from all succeeding models.

Table 4.5 Parameter Estimates for Equation 4.4 (Dependent Variable: *ADG*)

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	4.383	0.180	24.35	<.0001
Sex	-0.354	0.030	-11.97	<.0001
StartWt	-0.001	3.674E-04	-2.60	0.0094
Feed	-1.013	0.068	-14.86	<.0001
Arrival Season (Default = Season0)				
Season1	-0.069	0.047	-1.47	0.1420
Season2	-0.466	0.054	-8.57	<.0001
Season3	-0.099	0.049	-2.02	0.0430
Arrival Year (Default = Year06)				
Year07	-0.275	0.044	-6.31	<.0001
Year08	-0.232	0.044	-5.24	<.0001
Source (Default = Source0)				
Source1	-0.106	0.041	-2.58	0.0100
Source2	-0.472	0.092	-5.11	<.0001
Source3	0.092	0.034	2.70	0.0070
Source4	-0.215	0.090	-2.39	0.0169
Morbidity (Default = Morbidity0)				
Morbidity1	-0.438	0.041	-10.73	<.0001
Morbidity2	-1.137	0.057	-20.02	<.0001
Morbidity3	-2.082	0.092	-22.56	<.0001
Morbidity4	-0.479	0.148	-3.24	0.0012

Number of Observations = 3302
RMSE = 0.803
Adj. R^2 = 0.3604

As expected, the coefficient on sex is negative; those arriving as bulls have a lower ADG than those arriving as steers. The feed dummy variable was also negative; a limit-feed diet diminishes ADG. The coefficient on the starting weight variable had the expected sign; those arriving at heavier weights had lower ADG than those arriving at lower weights. Arrival seasons were mostly significant. Those that arrived in spring gained the best, followed by early summer (a tendency, not statistically significant), fall and late summer arrivals, respectively. This makes sense as the late summer arrivals are on trial during some of the hottest parts of the summer (July, August and September), though in terms of exposure to sun and heat, it would be expected that fall arrivals fare better than the early summer arrivals. However, it is possible that an age difference may exist between these two groups (fall and early summer), accounting for the discrepancy in expectations. There was a difference in ADG between the arrival years. 2006 was better for weight gain than 2008, and 2008 was slightly better than 2007. Source of the cattle was also highly significant. Calves from Sweetwater, TN and additional pick-ups gained the best; followed by Dickson, TN; Waynesboro, TN; Glasgow, KY; and Guthrie, KY, respectively. Finally, morbidity was as expected. Needing to be treated for BRD decreased ADG by about four-tenths of a pound, and additional treatments cost additional gain, another seven-tenths of a pound for the second treatment and more than nine-tenths of a pound beyond that for the third treatment. Treatment for another ailment was also found to decrease gain by nearly a half of a pound.

The estimated parameter coefficients for the RADG model (Equation 4.5) are shown in Table 4.6. Except for the *StartWt* variable which is significant at the five percent level, all other variables are significant at the one percent level.

Table 4.6 Parameter Estimates for Equation 4.5 (Dependent Variable: *RADG*)

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	6.698	0.411	16.28	<.0001
Sex	-0.755	0.070	-10.82	<.0001
StartWt	-0.002	0.001	-2.43	0.0150
Arrival Season (Default = Season0)				
Season1	1.069	0.095	11.22	<.0001
Season2	-0.642	0.114	-5.61	<.0001
Season3	0.550	0.100	5.53	0.0012
Arrival Year (Default = Year06)				
Year07	-1.051	0.095	-11.12	<.0001
Year08	-0.975	0.105	-9.32	<.0001
Source (Default = Source0)				
Source1	-0.475	0.097	-4.91	<.0001
Source2	-0.958	0.214	-4.48	<.0001
Source3	0.300	0.080	3.74	0.0002
Source4	-1.318	0.212	-6.20	<.0001
Morbidity (Default = Morbidity0)				
Morbidity1	-0.845	0.096	-8.79	<.0001
Morbidity2	-2.107	0.133	-15.90	<.0001
Morbidity3	-2.933	0.194	-15.09	<.0001
Morbidity4	-0.906	0.351	-2.58	0.0098

Number of Observations = 3342
RMSE = 1.903
Adj. R^2 = 0.3166

The RADG model produced very similar results to the ADG model. The sex and starting weight variables have negative signs as expected. The magnitude of the starting weight variable is larger, probably as a result of environmental variability felt nearest to arrival. Some cattle have been previously weaned and adjusted to feed and water, therefore they will spend more time feeding and watering than those just now becoming accustomed to their new conditions and thus will gain better. Furthermore, the magnitude of the sex dummy variable is larger for this time period which is consistent with the effects of castration being felt nearest the time of processing. The arrival year results were also the same though they have a much larger impact for the shorter timeframe from arrival to revaccination. The seasons gained more significance, however, how they impact gain relative to each other changed. This could also be due to the relatively short timeframe examined (an average of just 14 days compared to 44 days). Late summer was hardest on cattle, then spring, fall, and early summer. Arrival seasons also had more of an impact during this shorter timeframe. Source has a similar story as season, i.e., sources had a greater impact during the short timeframe. During the first two weeks, cattle from Glasgow, KY fared the worst, then Guthrie, KY; Waynesboro, TN; Dickson, TN; and Sweetwater, TN and additional pick-ups. All morbidity dummy variables were negative and significant, with those needing treatment multiple times falling behind those not needing treatment as many times. Furthermore, all the morbidity terms were significant and more greatly impacted RADG than ADG. This is contradictory to expectations. However, morbidity may have a larger impact on RADG than ADG because if cattle fall ill during the time from arrival to revaccination, they have the rest of the trial for compensatory gain to occur and mediate some of the effects of BRD. To reiterate, time from arrival to BRD treatment was not examined in this study, so it is not known that cattle had fallen ill prior to revaccination.

4.2.2 Metaphylaxis Treatment

The estimated parameter coefficients for the ADG model examining metaphylaxis treatment are shown in Table 4.7. The model explains 37% of the variability in ADG. All variables are significant at the 1% level except for *Source4*, which is significant at the 5% level, and *StartWt*, *Season1* and *Meta1*Sex*, which are significant at the 10% level.

Table 4.7 Parameter Estimates for Equation 4.6 (Dependent Variable: *ADG*)

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	4.256	0.181	23.52	<.0001
Sex	-0.337	0.034	-9.83	<.0001
StartWt	-0.001	3.704E-04	-1.70	0.0897
Feed	-1.136	0.076	-14.99	<.0001
Arrival Season (Default = Season0)				
Season1	-0.082	0.048	-1.71	0.0867
Season2	-0.521	0.070	-7.50	<.0001
Season3	-0.197	0.059	-3.35	0.0008
Arrival Year (Default = Year06)				
Year07	-0.175	0.049	-3.54	0.0004
Year08	-0.288	0.050	-5.74	<.0001
Source (Default = Source0)				
Source1	-0.113	0.041	-2.78	0.0055
Source2	-0.498	0.093	-5.36	<.0001
Source3	0.102	0.034	3.01	0.0026
Source4	-0.192	0.094	-2.04	0.0416
Morbidity (Default = Morbidity0)				
Morbidity1	-0.433	0.041	-10.60	<.0001
Morbidity2	-1.100	0.057	-19.23	<.0001
Morbidity3	-2.056	0.093	-22.14	<.0001
Morbidity4	-0.490	0.147	-3.33	0.0009
Metaphylaxis Treatment (Default = Metaphyl0)				
Metaphyl1	-0.384	0.090	-4.26	<.0001
Metaphyl2	0.253	0.083	3.04	0.0024
Metaphylaxis*Sex (Default = Meta0*Sex)				
*Meta1*Sex*	0.188	0.105	1.79	0.0738
*Meta2*Sex*	-0.214	0.077	-2.77	0.0056

Number of Observations = 3294
RMSE = 0.797
Adj. R^2 = 0.3657

The results for this ADG model are nearly identical to the results for the previous ADG model (Table 4.5) in terms of coefficient signs, magnitudes and interpretations. The main variables of interest in this model are the metaphylaxis terms. In this model, steers treated with

Draxxin are the base animals. Relative to these base animals, bulls treated with Draxxin gained 0.337 less pounds per day, steers treated with Micotil gained 0.384 less pounds per day, bulls treated with Micotil gained 0.533 less pounds per day, steers treated with Excede gained 0.253 more pounds per day and bulls treated with Excede gained 0.298 less pounds per day. In overall terms of performance, cattle treated with Excede gained the best, then those treated with Draxxin, followed by calves treated with Micotil.

The estimated parameter coefficients for the RADG model examining metaphylaxis treatment are shown in Table 4.8. The model explains 33% of the variability in RADG with most variables retaining or gaining significance. Notably, the *StartWt* variable has increased significance from the 10% to the 1% level, the *Morbidity4* has dropped to the 5% significance level, the *Meta1*Sex* variable has increased significance from 10% to 5% and the *Meta2*Sex* variable is no longer statistically significant.

Table 4.8 Parameter Estimates for Equation 4.7 (Dependent Variable: *RADG*)

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	6.601	0.410	16.11	<.0001
Sex	-0.828	0.079	-10.43	<.0001
StartWt	-0.002	0.001	-2.66	0.0079
Arrival Season (Default = Season0)				
Season1	1.196	0.094	12.66	<.0001
Season2	0.343	0.135	2.55	0.0108
Season3	1.007	0.107	9.43	<.0001
Arrival Year (Default = Year06)				
Year07	-1.001	0.098	-10.24	<.0001
Year08	-0.460	0.113	-4.06	<.0001
Source (Default = Source0)				
Source1	-0.479	0.094	-5.07	<.0001
Source2	-0.753	0.208	-3.61	0.0003
Source3	0.328	0.078	4.18	<.0001
Source4	-0.451	0.218	-2.06	0.0390
Morbidity (Default = Morbidity0)				
Morbidity1	-0.737	0.094	-7.84	<.0001
Morbidity2	-1.860	0.132	-14.06	<.0001
Morbidity3	-2.356	0.215	-10.97	<.0001
Morbidity4	-0.752	0.340	-2.21	0.0270
Metaphylaxis Treatment (Default = Metaphyl0)				
Metaphyl1	-1.246	0.205	-6.07	<.0001
Metaphyl2	-1.734	0.183	-9.48	<.0001
Metaphylaxis*Sex (Default = Meta0*Sex)				
*Meta1*Sex*	0.548	0.244	2.25	0.0244
*Meta2*Sex*	0.090	0.178	0.50	0.6152

Number of Observations = 3294

RMSE = 1.845

Adj. R^2 = 0.3296

All variables have the same signs and interpretations as the previous ADG model. As expected, sex and starting weight have a greater impact in this model. Also, like the other ADG/RADG coupling, the source and morbidity variables have greater impacts in the RADG model than the ADG model. The season variables have changed substantially from the ADG model to the RADG model. Most importantly, the signs on all the coefficients have changed from negative to positive, indicating that those arriving in spring now gain the worst instead of the best. Additionally, while early summer and fall have greater impacts in the shorter timeframe, late summer has a smaller impact in the period from arrival to revaccination. Again, the main variables of interest are the metaphylaxis terms, and steers treated with Draxxin are the base animals. Relative to these base animals, bulls treated with Draxxin gain 0.828 fewer pounds per day, steers treated with Micotil gain 1.246 fewer pounds per day, bulls treated with Micotil gain 1.526 fewer pounds per day, steers treated with Excede gain 1.734 fewer pounds per day, and bulls treated with Excede gain 2.562 fewer pounds per day. From arrival to revaccination, cattle treated with Draxxin have a performance advantage, and those treated with Micotil have a performance advantage over those treated with Excede.

In both these performance models Draxxin has a performance advantage over Micotil; however, calves administered Excede perform the worst through revaccination but the best over the course of the entire receiving trial. The conclusions suggest that Excede keeps cattle healthiest throughout the entire trial thus allowing those calves to stay on feed and gain weight and that Draxxin maintains good health better than Micotil, so Draxxin-treated cattle stay on feed and gain weight better than Micotil-treated cattle. Additionally, the performance changes of cattle administered Excede imply that those cattle get sick earlier in the trial and have a longer timeframe for compensatory gain to occur relative to those administered Draxxin and Micotil or that cattle administered Draxxin and Micotil require more multiple treatments than those administered Excede which allows Excede-treated cattle to experience greater compensatory gain. Morbidity will be analyzed in the next chapter in Sections 5.1.2 and 5.2.2.

4.3 Economic Results

4.3.1 Castration Timing

Calculations were made to determine what the breakeven purchase price of a calf is or how much cattle should be discounted at purchase in order to breakeven. In order to complete these calculations several prices and costs were estimated. These estimates are detailed below.

First, the early-castrated, healthy steer cost of gain (COG) was assumed to be $70/cwt, based on 6 pounds feed/pound gain (Gill, Barnes, and Lalman) with the ration costing $180/ton and including labor, equipment and fuel costs. Since castration is stressful, late-castrated steers tend to have decreased feed intake and gain-to-feed ratios. Therefore, late-castrated steers likely would have lower cost/head and higher cost/cwt than early-castrated steers. Both Faulkner et al. (1992) and Worrell, Clanton, and Calkins (1987) found that bulls castrated between 470 and 506 pounds exhibited these characteristics, with decreases in feed intake and feed efficiency of 5-6%. As such, it was assumed that late-castrated steers had no less than 95% of the cost/head of an early-castrated steer. Though feed is the primary component of COG, other costs such as labor and fuel would not decrease with the diminished feed intake. See Table 4.9 for an example. The *Steer* is the base animal. *Bull 1* shows the minimum total cost as a percentage of the base animal if feed is the only cost of gain and feed intake decreased by 5%, and *Bull 2* shows total cost per head when feed is not the only cost of gain and therefore has a higher percentage total cost compared to the *Steer* than *Bull 1*.

Table 4.9 Illustration of Cost per Head as a Percentage of Base Animal Cost per Head

	Steer	*Bull 1*	*Bull 2*
Cost, $/hd	$100.00	$95.00	$96.00
Cost, $/hd as % of *Steer* cost, $/hd		95%	96%

This same reasoning regarding lower total cost and higher cost of gain applies to healthy and morbid steers. Daniels et al. (2000) determined that healthy calves had both more feeding bouts per day and spent more time feeding per day, as much as 33% more, than morbid calves. Specifically, Hutcheson and Cole (1986) found that after 56 days, feed intake for morbid calves was 11% less than healthy calves. Therefore, to accommodate for the varying degrees of morbidity, it was assumed that cattle receiving one treatment, two treatments, or three treatments for BRD had no less than 91%, 88%, and 81% of the cost/head relative to healthy steers, respectively. See Table 4.10 for an illustration of the minimum total cost of the treated steer as a percentage of the total cost of the base animal. *Steer* is the base animal (never treated), *Steer1* has been treated once, *Steer 2* has been treated twice, and *Steer 3*, treated three times.

Table 4.10 Minimum Total Costs for Steers Treated for BRD as a Percentage of the Total Cost of a Healthy Steer

	Steer	*Steer 1*	*Steer 2*	*Steer 3*
Cost, $/hd	$100.00	$91.00	$88.00	$81.00
Cost, $/hd as % of *Steer* cost, $/hd		91%	88%	81%

The diminished feed intake effects of castration and morbidity would presumably be cumulative. Table 4.11 shows the minimum total cost of the treated bull as a percentage of the total cost of the base animal. *Steer* is the base animal (never treated), *Bull 1* has been treated once, *Bull 2* has been treated twice, and *Bull 3* has been treated three times.

Table 4.11 Minimum Total Costs for Bulls Treated for BRD as a Percentage of the Total Cost of a Healthy Steer

	Steer	*Bull 1*	*Bull 2*	*Bull 3*
Cost, $/hd	$100.00	$86.00	$83.00	$76.00
Cost, $/hd as % of *Steer* cost, $/hd		86%	83%	76%

Treatment costs were estimated using dosage costs only, utilizing the lowest October 2009 prices from Valley Vet Supply (Marysville, KS) for a 525 pound calf (the average of the starting and ending weight averages). For cattle diagnosed with BRD, the first treatment administered was Baytril at $16/dose (Bayer Animal Health, Shawnee Mission, KS), the second treatment, Nuflor at $17/dose (Intervet Schering-Plough Animal Health, Roseland, NJ), and the third treatment was Bio-Mycin at $2/dose (Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO). Additionally, the cost of castration including equipment and labor was assumed to be $5/head.

Selling prices of the calves were estimated using www.BeefBasis.com on October 16, 2009. Prices were forecasted in Kansas, selling 25 head at Farmers and Ranchers Livestock Commission, as large and medium/large frame and grades 1-2. Since spring was the most common arrival season, the purchase date was set at March 15, 2010, thus the selling date 44 days later was April 28, 2010. The feeder cattle futures price, as determined by www.BeefBasis.com for April 28, was $96.37/cwt, and the corn futures price was $3.94/bu.

Several items need to be calculated in order to attain breakeven purchase prices or determine how much a bull and/or morbid calf would need to be discounted relative to a healthy steer calf. Using the results in Table 4.5 from Equation 4.4, the first item calculated is projected ADG for early- and late-castrated steers, each treated no times, once, twice or three times for BRD, holding all other variables at their averages or most frequent observation. The projected ending weight 44 days later was determined. The revenue per head was then calculated from projected ending weights and forecasted prices.

Each cost/head was calculated using the projected weight gain and the COG/cwt as situationally determined. As previously mentioned, the COG for the healthy steer was assumed to be $70/cwt, and each other COG/cwt was set so that the cost/head for a particular calf, e.g., an early-castrated steer treated once, as a percentage of the healthy steer was consistent with the decreases previously identified in (Table 4.9, Table 4.10, and Table 4.11), e.g., 91-100% for this example calf with emphasis on the 91%. Added costs for castration and morbidity are their own line-items. Then all costs per head were subtracted from the revenue per head. The steer mortality rate for this study was 0.85% compared to 2.81% for bulls. To incorporate these potential losses, the *Revenue-Cost, $/hd* was multiplied by the respective mortality rate to obtain the *Potential Mortality Costs, $/hd*. These mortality costs were then subtracted from the *Revenue-Cost, $/hd* to find the gross revenue; this number was then divided by the starting weight and multiplied by 100 to obtain the breakeven purchase price for the respective calf. To obtain the discounts to apply to bulls or morbid steers and bulls, subtract the breakeven purchase price of the discounted animal from the base animal, i.e., the healthy steer.

The breakeven purchase prices and discounts are presented for the typical calf arriving in spring 2007 from Dickson, TN at 459 pounds and put on an ad libitum diet (Table 4.12), the typical calf arriving at 400 pounds (Table 4.13), and the typical calf arriving at 500 pounds (Table 4.14). These three weights were examined because 459 pounds was the average starting weight, and 400 pounds and 500 pounds were easy to work with numbers that would show how the prices and discounts would vary for both the smaller and larger than average stocker calf. Morbid steers arriving at 459 pounds should be discounted $4.17/cwt, $11.40/cwt, and

$16.19/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer. Arriving at 459 pounds, a healthy bull should be discounted $4.58/cwt relative to a healthy steer, and if the bull is expected to be treated once, twice, or three times for BRD, it should be discounted $8.34/cwt, $15.33/cwt, and $20.25/cwt, respectively. Morbidity increases costs, thus in order to breakeven on calves of the same weight, those requiring treatment for BRD need to be discounted at purchase. Bulls have the additional costs of castration and exhibit poorer performance, thus necessitating discounts at purchase. The combination of castration and morbidity further increased the discount needed to breakeven.

When looking at cattle arriving at lighter weights, i.e., 400 pounds, and heavier weights, i.e., 500 pounds, the discounts change. All discounts are greater for the lighter weight arrivals and lesser for the heavier weight arrivals compared to the average arrival weight of 459 pounds. This is contrary to intuition. Castration is more stressful for heavier weight bulls and should inhibit performance and potentially increase susceptibility to disease relative to lighter weight bulls and thus have larger, not smaller, discounts to breakeven, but then again no sex, starting weight interaction term was included in the model. However, due to the price slide that exists, buyers pay more per hundredweight for lighter weight cattle than heavier weight cattle. It is possible that because a buyer is paying more at the onset for lighter calves, the discount must be greater in order to compensate for lost performance/increased morbidity.

Table 4.12 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 459 lbs

	Steer				Bull			
	No Treat[†]	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Projected ADG	3.67	3.23	2.53	1.59	3.31	2.88	2.18	1.23
Ending Weight	620.42	601.16	570.39	528.83	604.85	585.59	554.82	513.27
Ending Price, $/cwt	$106.70	$108.22	$110.75	$114.23	$107.90	$109.51	$112.01	$115.62
Revenue, $/hd	$661.99	$650.57	$631.71	$604.09	$652.64	$641.28	$621.46	$593.44
Cost of Gain, $/cwt	$70.00	$73.79	$92.01	$136.10	$74.86	$78.67	$99.95	$163.99
Cost, $/hd	$112.99	$104.90	$102.49	$95.04	$109.18	$99.59	$95.77	$88.99
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Revenue - Cost, $/hd	$548.99	$529.67	$496.22	$474.04	$538.46	$520.70	$487.68	$464.45
Potential Mortality Costs, $/hd	$4.67	$4.50	$4.22	$4.03	$15.13	$14.63	$13.70	$13.05
Gross Revenue - Mortality Costs, $/hd	$544.33	$525.17	$492.00	$470.01	$523.33	$506.07	$473.98	$451.40
BE Purchase Price, $/cwt	$118.59	$114.42	$107.19	$102.40	$114.01	$110.25	$103.26	$98.34
Price Disc to BE, $/cwt		-$4.17	-$11.40	-$16.19	-$4.58	-$8.34	-$15.33	-$20.25
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd		92.8%	90.7%	84.1%	96.6%	88.1%	84.8%	78.8%

[†] Base animal to which other animals are being compared

Table 4.13 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 400 lbs

	Steer				Bull			
	No Treat[†]	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Projected ADG	3.72	3.29	2.59	1.64	3.37	2.93	2.23	1.29
Ending Weight	563.90	544.64	513.87	472.31	548.33	529.07	498.30	456.75
Ending Price, $/cwt	$111.25	$112.85	$115.54	$119.30	$112.60	$114.23	$116.95	$120.68
Revenue, $/hd	$627.34	$614.63	$593.72	$563.47	$617.42	$604.36	$582.77	$551.20
Cost of Gain, $/cwt	$70.00	$73.73	$91.53	$133.83	$74.77	$78.50	$99.19	$159.88
Cost, $/hd	$114.73	$106.64	$104.22	$96.78	$110.92	$101.32	$97.51	$90.73
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Revenue - Cost, $/hd	$512.61	$491.99	$456.50	$431.69	$501.51	$482.04	$447.25	$420.48
Potential Mortality Costs, $/hd	$4.36	$4.18	$3.88	$3.67	$14.09	$13.55	$12.57	$11.82
Gross Revenue - Mortality Costs, $/hd	$508.25	$487.80	$452.62	$428.02	$487.42	$468.49	$434.69	$408.66
BE Purchase Price, $/cwt	$127.06	$121.95	$113.16	$107.01	$121.85	$117.12	$108.67	$102.16
Price Disc to BE, $/cwt		-$5.11	-$13.91	-$20.06	-$5.21	-$9.94	-$18.39	-$24.90
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd		92.9%	90.8%	84.4%	96.7%	88.3%	85.0%	79.1%

[†] Base animal to which other animals are being compared

Table 4.14 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 500 lbs

	Steer				Bull			
	No Treat[†]	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**	**1 Treat**	**2 Treat**	**3 Treat**
Projected ADG	3.63	3.19	2.49	1.55	3.28	2.84	2.14	1.19
Ending Weight	659.70	640.44	609.67	568.11	644.13	624.87	594.10	552.54
Ending Price, $/cwt	$103.62	$105.15	$107.50	$110.92	$104.84	$106.31	$108.78	$112.26
Revenue, $/hd	$683.58	$673.42	$655.39	$630.15	$675.31	$664.30	$646.26	$620.29
Cost of Gain, $/cwt	$70.00	$73.84	$92.35	$137.77	$74.91	$78.79	$100.50	$167.07
Cost, $/hd	$111.79	$103.70	$101.28	$93.84	$107.97	$98.38	$94.57	$87.79
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Revenue - Cost, $/hd	$571.79	$553.72	$521.11	$501.31	$562.33	$544.92	$513.69	$492.50
Potential Mortality Costs, $/hd	$4.86	$4.71	$4.43	$4.26	$15.80	$15.31	$14.43	$13.84
Gross Revenue - Mortality Costs, $/hd	$566.93	$549.01	$516.68	$497.05	$546.53	$529.61	$499.26	$478.66
BE Purchase Price, $/cwt	$113.39	$109.80	$103.34	$99.41	$109.31	$105.92	$99.85	$95.73
Price Disc to BE, $/cwt		-$3.58	-$10.05	-$13.98	-$4.08	-$7.46	-$13.53	-$17.65
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd		92.8%	90.6%	83.9%	96.6%	88.0%	84.6%	78.5%

[†] Base animal to which other animals are being compared

4.3.2 Metaphylaxis Treatment

Like was done with castration timing, calculations were made to determine what the breakeven purchase price of a calf is or how much cattle should be discounted at purchase given different treatment regimens. In order to complete these calculations several prices and costs were estimated. These estimates are exactly the same as before with one addition, as detailed below.

In addition to castration and BRD treatment costs, metaphylaxis drug costs were also needed. Metaphylaxis costs were estimated using dosage costs only, utilizing the lowest October 2009 prices from Valley Vet Supply (Marysville, KS) for the average 459 pound arrival calf. Dosage costs for Draxxin were determined to be $20.28/head, $9.36/head for Micotil, and $11.91/head for Excede.

All calculations to arrive at breakeven purchase prices and discounts to breakeven are exactly the same as castration timing. Metaphylaxis costs were also given their own line-item. Even though starting weight is statistically significant, starting weight was not varied in these calculations. The typical calf is the same as before: arrived spring 2007 from Dickson, TN at 459 pounds and put on an ad libitum diet.

The results for purchased steers and bulls treated no times, once, twice, and three times for BRD and administered Draxxin on arrival are presented in Table 4.15. The complementary results for cattle administered Micotil and Excede on arrival are presented in Table 4.16 and Table 4.17, respectively. Breakeven purchase prices and discounts are also compared between the drugs for both steers and bulls in Table 4.18 and Table 4.19, respectively.

Morbid steers arriving at 459 pounds and being treated with Draxxin on arrival should be discounted \$3.71/cwt, \$10.76/cwt, and \$15.59/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer. Arriving at 459 pounds and administered Draxxin on arrival, a healthy bull should be discounted \$4.14/cwt relative to a healthy steer, and if the bull is expected to be treated once, twice, or three times for BRD, it should be discounted \$8.17/cwt, \$14.99/cwt, and \$19.38/cwt, respectively. Morbid steers arriving at 459 pounds and being treated with Micotil on arrival should be discounted \$3.76/cwt, \$11.05/cwt, and \$16.11/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer. Arriving at 459 pounds and administered Micotil on arrival, a healthy bull should be discounted \$3.06/cwt relative to a healthy steer, and if the bull is expected to be treated once, twice, or three times for BRD, it should be discounted \$7.12/cwt, \$14.12/cwt, and \$18.61/cwt, respectively. Morbid steers arriving at 459 pounds and being treated with Excede on arrival should be discounted \$3.64/cwt, \$10.77/cwt, and \$15.33/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer. Arriving at 459 pounds and administered Excede on arrival, a healthy bull should be discounted \$5.57/cwt relative to a healthy steer, and if the bull is expected to be treated once, twice, or three times for BRD, it should be discounted \$9.28/cwt, \$16.09/cwt, and \$20.56/cwt, respectively. Like before, morbidity increases costs, thus in order to breakeven on calves of the same weight, those requiring treatment for BRD need to be discounted at purchase. Bulls have the additional costs of castration and exhibit poorer performance, thus necessitating discounts at purchase. The combination of castration and morbidity further increased the discount needed to breakeven.

When comparing across treatments, morbid steers arriving at 459 pounds and being treated with Excede on arrival should be discounted the same as previously reported ($5.70/cwt, $13.04/cwt, and $19.15/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer administered Excede on arrival). But, morbid steers arriving at 459 pounds and being treated with Draxxin on arrival should be discounted $6.88/cwt, $13.94/cwt, and $18.76/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer administered Excede on arrival. Even if not requiring BRD treatment, steers being treated with Draxxin on arrival need to be discounted $3.18/cwt relative to healthy steers treated with Excede on arrival. Morbid steers arriving at 459 pounds and being treated with Micotil on arrival should be discounted $6.70/cwt, $13.99/cwt, and $19.05/cwt if they are going to be treated for BRD once, twice, or three times, respectively, relative to a healthy steer administered Excede on arrival. Even if not requiring BRD treatment, steers being treated with Micotil on arrival need to be discounted $2.94/cwt relative to healthy steers treated with Excede on arrival.

Bulls exhibit the same discount patterns as steers with bulls being treated with Micotil on arrival requiring larger discounts to breakeven than bulls treated with Excede. Additionally, all bulls being treated with Draxxin on arrival require larger discounts to breakeven than bulls treated with Micotil. However, steers administered Micotil on arrival and treated for BRD two or three times require larger discounts than steers administered Draxxin on arrival and treated for BRD two or three times.

These results indicate that the benefits of using Excede overcome the larger dosage costs relative to Micotil, but only in steers treated twice or more does Draxxin overcome the larger dosage cost relative to Micotil. This is probably attributable to the performance advantages of

Excede-treated calves relative to both Draxxin- and Micotil-treated calves combined with the relatively cheaper dosage costs of Excede relative to Draxxin.

Table 4.15 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 459 lbs and Administered Draxxin on Arrival

	Steer				Bull			
	No Treat†	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**	**1 Treat**	**2 Treat**	**3 Treat**
Projected ADG	3.79	3.36	2.69	1.74	3.45	3.02	2.36	1.40
Ending Weight	625.86	606.79	577.47	535.41	611.02	591.95	562.63	520.56
Ending Price, $/cwt	$106.30	$107.80	$110.24	$113.77	$107.48	$109.01	$111.40	$114.99
Revenue, $/hd	$665.29	$654.12	$636.61	$609.13	$656.72	$645.29	$626.77	$598.60
Cost of Gain, $/cwt	$70.00	$72.26	$88.58	$128.01	$73.76	$78.03	$96.91	$147.82
Cost, $/hd	$116.80	$106.79	$104.95	$97.81	$112.13	$103.75	$100.43	$91.01
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Added Cost: Meta Treatment, $/hd	$20.28	$20.28	$20.28	$20.28	$20.28	$20.28	$20.28	$20.28
Revenue - Cost, $/hd	$528.21	$511.05	$478.38	$456.05	$519.31	$500.26	$468.06	$447.31
Potential Mortality Costs, $/hd	$4.49	$4.34	$4.07	$3.88	$14.59	$14.06	$13.15	$12.57
Gross Revenue - Mortality Costs, $/hd	$523.72	$506.71	$474.31	$452.17	$504.72	$486.20	$454.91	$434.74
BE Purchase Price, $/cwt	$114.10	$110.39	$103.34	$98.51	$109.96	$105.93	$99.11	$94.71
Price Disc to BE, $/cwt		-$3.71	-$10.76	-$15.59	-$4.14	-$8.17	-$14.99	-$19.38
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd	100.0%	91.4%	89.9%	83.7%	96.0%	88.8%	86.0%	77.9%

†Base animal to which other animals are being compared

Table 4.16 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 459 lbs and Administered Micotil on Arrival

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Projected ADG	3.41	2.97	2.31	1.35	3.26	2.83	2.16	1.20
Ending Weight	608.96	589.89	560.57	518.50	602.40	583.33	554.01	511.94
Ending Price, $/cwt	$107.64	$109.17	$111.57	$115.16	$108.20	$109.74	$112.16	$115.78
Revenue, $/hd	$655.48	$643.98	$625.43	$597.11	$651.79	$640.14	$621.38	$592.73
Cost of Gain, $/cwt	$77.89	$81.54	$103.30	$164.73	$78.02	$83.17	$106.00	$172.42
Cost, $/hd	$116.80	$106.73	$104.92	$98.02	$111.88	$103.41	$100.71	$91.29
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Added Cost: Meta Treatment, $/hd	$9.36	$9.36	$9.36	$9.36	$9.36	$9.36	$9.36	$9.36
Revenue - Cost, $/hd	$529.32	$511.89	$478.15	$454.73	$525.56	$506.38	$473.31	$452.08
Potential Mortality Costs, $/hd	$4.50	$4.35	$4.06	$3.87	$14.77	$14.23	$13.30	$12.70
Gross Revenue - Mortality Costs, $/hd	$524.82	$507.54	$474.08	$450.87	$510.79	$492.15	$460.01	$439.38
BE Purchase Price, $/cwt	$114.34	$110.58	$103.29	$98.23	$111.28	$107.22	$100.22	$95.73
Price Disc to BE, $/cwt		-$3.76	-$11.05	-$16.11	-$3.06	-$7.12	-$14.12	-$18.61
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd	100.0%	91.4%	89.8%	83.9%	95.8%	88.5%	86.2%	78.2%

†Base animal to which other animals are being compared

Table 4.17 Purchase Prices and Price Discounts to Breakeven for Typical Calf Arriving at 459 lbs and Administered Excede on Arrival

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Projected ADG	4.04	3.61	2.95	1.99	3.49	3.06	2.39	1.44
Ending Weight	636.97	617.90	588.58	546.52	612.73	593.66	564.34	522.27
Ending Price, $/cwt	$105.44	$106.93	$109.25	$112.75	$107.32	$108.85	$111.32	$114.90
Revenue, $/hd	$671.62	$660.72	$643.03	$616.20	$657.58	$646.20	$628.22	$600.09
Cost of Gain, $/cwt	$65.63	$67.20	$81.08	$111.25	$73.59	$76.70	$95.35	$144.49
Cost, $/hd	$116.80	$106.78	$105.06	$97.36	$113.13	$103.28	$100.44	$91.42
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Added Cost: Meta Treatment, $/hd	$11.91	$11.91	$11.91	$11.91	$11.91	$11.91	$11.91	$11.91
Revenue - Cost, $/hd	$542.91	$526.04	$493.06	$471.92	$527.54	$510.01	$477.87	$456.76
Potential Mortality Costs, $/hd	$4.61	$4.47	$4.19	$4.01	$14.82	$14.33	$13.43	$12.83
Gross Revenue - Mortality Costs, $/hd	$538.30	$521.57	$488.87	$467.91	$512.72	$495.68	$464.45	$443.92
BE Purchase Price, $/cwt	$117.28	$113.63	$106.51	$101.94	$111.70	$107.99	$101.19	$96.72
Price Disc to BE, $/cwt		-$3.64	-$10.77	-$15.33	-$5.57	-$9.28	-$16.09	-$20.56
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd	100.0%	91.4%	89.9%	83.4%	96.9%	88.4%	86.0%	78.3%

†Base animal to which other animals are being compared

Table 4.18 Purchase Prices and Price Discounts to Breakeven, Comparing Metaphylaxis Drugs, for Typical Steer Calf Arriving at 459 lbs

	Steer Administered Draxxin				Steer Administered Micotil				Steer Administered Excede			
	No Treat	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**[†]	**1 Treat**	**2 Treat**	**3 Treat**
Projected ADG	3.79	3.36	2.69	1.74	3.41	2.97	2.31	1.35	4.04	3.61	2.95	1.99
Ending Weight	625.86	606.79	577.47	535.41	608.96	589.89	560.57	518.50	636.97	617.90	588.58	546.52
Ending Price, $/cwt	$106.30	$107.80	$110.24	$113.77	$107.64	$109.17	$111.57	$115.16	$105.44	$106.93	$109.25	$112.75
Revenue, $/hd	$665.29	$654.12	$636.61	$609.13	$655.48	$643.98	$625.43	$597.11	$671.62	$660.72	$643.03	$616.20
Cost of Gain, $/cwt	$70.00	$72.26	$88.58	$128.01	$77.89	$81.54	$103.30	$164.73	$65.63	$67.20	$81.08	$111.25
Cost, $/hd	$116.80	$106.79	$104.95	$97.81	$116.80	$106.73	$104.92	$98.02	$116.80	$106.78	$105.06	$97.36
Added Cost: Castration, $/hd	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Added Cost: Meta Treatment, $/hd	$20.28	$20.28	$20.28	$20.28	$9.36	$9.36	$9.36	$9.36	$11.91	$11.91	$11.91	$11.91
Revenue - Cost, $/hd	$528.21	$511.05	$478.38	$456.05	$529.32	$511.89	$478.15	$454.73	$542.91	$526.04	$493.06	$471.92
Potential Mortality Costs, $/hd	$4.49	$4.34	$4.07	$3.88	$4.50	$4.35	$4.06	$3.87	$4.61	$4.47	$4.19	$4.01
Gross Revenue - Mortality Costs, $/hd	$523.72	$506.71	$474.31	$452.17	$524.82	$507.54	$474.08	$450.87	$538.30	$521.57	$488.87	$467.91
BE Purchase Price, $/cwt	$114.10	$110.39	$103.34	$98.51	$114.34	$110.58	$103.29	$98.23	$117.28	$113.63	$106.51	$101.94
Price Disc to BE, $/cwt	-$3.18	-$6.88	-$13.94	-$18.76	-$2.94	-$6.70	-$13.99	-$19.05		-$3.64	-$10.77	-$15.33
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd	100.0%	91.4%	89.9%	83.7%	100.0%	91.4%	89.8%	83.9%	100.0%	91.4%	89.9%	83.4%

[†]Base animal to which other animals are being compared

Table 4.19 Purchase Prices and Price Discounts to Breakeven, Comparing Metaphylaxis Drugs, for Typical Bull Calf Arriving at 459 lbs

	Bull Administered Draxxin				Bull Administered Micotil				Bull Administered Excede			
	No Treat	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat†**	**1 Treat**	**2 Treat**	**3 Treat**
Projected ADG	3.45	3.02	2.36	1.40	3.26	2.83	2.16	1.20	3.49	3.06	2.39	1.44
Ending Weight	611.02	591.95	562.63	520.56	602.40	583.33	554.01	511.94	612.73	593.66	564.34	522.27
Ending Price, $/cwt	$107.48	$109.01	$111.40	$114.99	$108.20	$109.74	$112.16	$115.78	$107.32	$108.85	$111.32	$114.90
Revenue, $/hd	$656.72	$645.29	$626.77	$598.60	$651.79	$640.14	$621.38	$592.73	$657.58	$646.20	$628.22	$600.09
Cost of Gain, $/cwt	$73.76	$78.03	$96.91	$147.82	$78.02	$83.17	$106.00	$172.42	$73.59	$76.70	$95.35	$144.49
Cost, $/hd	$112.13	$103.75	$100.43	$91.01	$111.88	$103.41	$100.71	$91.29	$113.13	$103.28	$100.44	$91.42
Added Cost: Castration, $/hd	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
Added Cost: BRD Treatment, $/hd	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00	$0.00	$16.00	$33.00	$35.00
Added Cost: Meta Treatment, $/hd	$20.28	$20.28	$20.28	$20.28	$9.36	$9.36	$9.36	$9.36	$11.91	$11.91	$11.91	$11.91
Revenue - Cost, $/hd	$519.31	$500.26	$468.06	$447.31	$525.56	$506.38	$473.31	$452.08	$527.54	$510.01	$477.87	$456.76
Potential Mortality Costs, $/hd	$14.59	$14.06	$13.15	$12.57	$14.77	$14.23	$13.30	$12.70	$14.82	$14.33	$13.43	$12.83
Gross Revenue - Mortality Costs, $/hd	$504.72	$486.20	$454.91	$434.74	$510.79	$492.15	$460.01	$439.38	$512.72	$495.68	$464.45	$443.92
BE Purchase Price, $/cwt	$109.96	$105.93	$99.11	$94.71	$111.28	$107.22	$100.22	$95.73	$111.70	$107.99	$101.19	$96.72
Price Disc to BE, $/cwt	-$1.74	-$5.78	-$12.59	-$16.99	-$0.42	-$4.48	-$11.48	-$15.98		-$3.71	-$10.52	-$14.99
Cost, $/hd as % of *Steer, No Treat* Cost, $/hd	96.0%	88.8%	86.0%	77.9%	95.8%	88.5%	86.2%	78.2%	96.9%	88.4%	86.0%	78.3%

†Base animal to which other animals are being compared

CHAPTER 5 - MORBIDITY

5.1 Modeling

This study next looked at the probability of whether or not a calf would get sick and, if he did fall ill, what is the probability that he will need to be treated for bovine respiratory disease (BRD) more than once. This was accomplished through the estimation of four logit models in SAS. These morbidity models are similar to the performance models where morbidity instead of average daily gain is the dependent variable. Logit models were estimated instead of probit models as they are more commonplace (Schroeder, 2009), and unless the samples are large with enough observations at the tails, assuming either a logistic (logit model) or normal (probit model) distribution will likely result in very similar results (Maddala, 2008). Logit models enable the estimation of the probability of a specific event, i.e., the dependent variable, occurring. In binary logit models, the dependent variable can only take on two values where in the ordered logit model the dependent variable can take on multiple values. Both binary and ordered logit models were estimated since one dependent variable in this study, *MorbidityYes*, can take on only the values 0 or 1 while the other dependent variable, *Morbidity*, can take on the values 0, 1, 2 or 3.

The empirical form of a binary logit model is as follows:

(5.1) $Prob(y_i = 1) = F(x, \beta)$

$$F(x_i, \beta) = \frac{1}{1 + exp\,(-\beta' x_i)},$$

where *i* refers to the individual calf, y_i is the binary variable dependent upon the explanatory variables x, and β are parameters to be estimated. For the binary logit model in this chapter, $y_i = 1$ if a calf was ever treated for BRD, and $y_i = 0$ if a calf was never treated for BRD.

The marginal effects are calculated as:

(5.2) $$\frac{\partial E(y_i|x_i)}{\partial x_{i,j}} = \frac{exp(\beta' x_i)}{\left(1+exp(\beta' x_i)\right)^2} * \beta_j.$$

The latent form of an ordered logit model is as follows:

(5.3) $$y_i^* = x_i'\beta + \varepsilon_i,$$

where *i* refers to the individual calf, y_i^* is an unobservable variable linearly dependent on the explanatory variables x, and ε is a random error term. In these models, random error is also assumed to be logistically distributed, i.e., $F(\varepsilon_i) = \frac{1}{1+exp\ (-\varepsilon_i)}$. The observed dependent variables y_i are based on y_i^* where:

(5.4) $$y_i = 1\ if\ y_i^* \leq \mu_1$$

$$y_i = 2\ if\ \mu_1 < y_i^* \leq \mu_2$$

$$y_i = 3\ if\ \mu_2 < y_i^* \leq \mu_3$$

$$\vdots \qquad \vdots$$

$$y_i = J\ if\ \mu_{J-1} < y_i^*,$$

where the μ_k thresholds are unknown values to be estimated along with the β coefficients, and *J* is the number of categories. For these models the thresholds are not directly interpretable and thus are not reported or discussed. The dependent variable y_i is determined by the model being estimated, and for the ordered logit model in this chapter, $y_i = 0$ if a calf was never treated for BRD, $y_i = 1$ if a calf was treated for BRD once, $y_i = 2$ if a calf was treated for BRD twice, and $y_i = 3$ if a calf was treated for BRD three times. Since the random error is assumed to be logistically distributed, the probabilities of y_i are calculated as follows:

(5.5) $Prob(y_i = 1) = Prob(x_i'\beta + \varepsilon_i \leq \mu_1) = \frac{1}{1+exp\,(x_i'\beta-\mu_1)}$,

$$Prob(y_i = 2) = Prob(x_i'\beta + \varepsilon_i \leq \mu_2) - Prob(x_i'\beta + \varepsilon_i \leq \mu_1)$$
$$= \frac{1}{1+exp(x_i'\beta-\mu_2)} - \frac{1}{1+exp(x_i'\beta-\mu_1)},$$

$$Prob(y_i = 3) = Prob(x_i'\beta + \varepsilon_i \leq \mu_3) - Prob(x_i'\beta + \varepsilon_i \leq \mu_2)$$
$$= \frac{1}{1+exp(x_i'\beta-\mu_3)} - \frac{1}{1+exp(x_i'\beta-\mu_2)},$$

$$\vdots \qquad \vdots$$

$$Prob\,(y_i = J) = Prob\big(\mu_{J-1} \leq x_i'\beta + \varepsilon_i\big) = 1 - \frac{1}{1+exp\,(x_i'\beta-\mu_{J-1})}.$$

The marginal effects associated with the above probabilities are calculated as follows:

(5.6) $$\frac{\partial Prob(y_i=J)}{\partial \mathrm{x_{i,j}}} = -\beta_J \left[\frac{exp\,(x_i'\beta-\mu_J)}{\big(1+exp(x_i'\beta-\mu_J)} - \frac{exp\,(x_i'\beta-\mu_{J-1})}{\big(1+exp(x_i'\beta-\mu_{J-1})\big)^2}\right],$$

where $\mu_0 = -\infty$ and $\mu_J = \infty$ (Bolte, 2007).

5.1.1 Castration Timing

The factors that aid in explaining the variability in gain are also expected to affect the probability of cattle contracting BRD and needing treatment. The first model simply uses morbidity as a binary variable, i.e., whether or not a calf will ever require treatment for BRD:

(5.7) $$MorbidityYes = f\begin{pmatrix} sex, starting\ weight, arrival\ season, arrival\ year \\ source, situational\ considerations \end{pmatrix}.$$

Again, castration is a stressor; the sex variable is expected to be positive, i.e., those arriving as bulls are more likely to contract a respiratory complex. The weight coefficient is expected to be negative; using weight as an indication of health (and assuming cattle are of similar age), heavier animals should be healthier than lighter animals. The signs of the season, source, and arrival year variables are ambiguous, but it is expected that some seasons, sources and years are factors that would make calves more or less apt to come down with BRD. The hotter summer months are more stressful and could increase susceptibility to disease. Some sources may sell healthier cattle or engage in management techniques that promote rather than repress immunological responses. Therefore the empirical logit model estimated is as follows:

$$(5.8)\quad MorbidityYes = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \beta_{12} Feed),$$

where

MorbidityYes = a dummy variable for BRD treatment (0 = never treated for BRD, 1 = treated for BRD)

$Season_s$ = a set of dummy variables for arrival season (*s* = spring, early summer, late summer, fall; default = spring)

$Year_y$ = a set of dummy variables for arrival year (*y* = 2006, 2007, 2008; default = 2006)

$Source_r$ = a set of dummy variables for lot source (*r* = Dickson, TN; Waynesboro, TN; Guthrie, KY; Sweetwater, TN and additional pick-ups; Glasgow, KY; default = Dickson, TN)

and all other variables are defined in Table 4.1.

This model was followed up with an ordered logit model in an attempt to determine what factors may increase the likelihood of having to be treated for BRD multiple times versus just once or not at all. This mirrors the binary logit model with the exception of the dependent variable being *Morbidity* instead of *MorbidityYes*:

$$(5.9)\quad Morbidity_m = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \beta_{12} Feed)$$

where all variables are as defined in Equation 5.8, Table 4.1, and

$Morbidity_m$ = a set of dummy variables for morbidity (*m* = 0 if never treated for BRD, 1 if treated once for BRD, 2 if treated twice for BRD, 3 if treated three times for BRD; default = 0).

5.1.2 Metaphylaxis Treatment

Along these same lines, these two logit models were estimated to determine if one metaphylaxis treatment was better than the others in terms of maintaining good health. Therefore, both the conceptual and empirical models are nearly identical to the prior logit models, with the additions of both the metaphylaxis dummy variables and metaphylaxis, sex interaction variables. The first binary logit model estimated is:

$$(5.10) \quad MorbidityYes = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s\, Season_s + \sum_{y=6}^{7} \beta_y\, Year_y + \sum_{r=8}^{11} \beta_r\, Source_r + \beta_{12}\text{Feed} + \sum_{p=13}^{14} Metaphyl_p + \sum_{p=15}^{16} Meta_p * Sex),$$

where

$Metaphyl_p$= a set of dummy variables for metaphylaxis treatment (*p* = Draxxin, Micotil, Excede; default = Draxxin)

$Meta_p$*Sex* = a set of interaction dummy variables for metaphylaxis treatment*sex (*p* = Draxxin, Micotil, Excede; default = Draxxin*Sex)

and all other variables are as defined in Equation 5.8 and Table 4.1.

The expectations of the signs and magnitudes of the coefficients are the same as for those in Equation 5.8. The metaphylaxis coefficients are expected to be significant though there are no prior expectations, before estimating the models, for which treatment is most effective. Given the performance results that have already been presented, it is expected that overall Excede is the most effective metaphylaxis treatment. Additionally, the interaction terms will be significant if castration timing plays a significant role in metaphylaxis treatment efficacy.

Similarly, the ordered logit model for this subset of data to determine the probability of how many times a calf is to be treated for BRD is estimated as follows:

$$(5.11) \quad Morbidity_m = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \sum_{s=3}^{5} \beta_s Season_s + \sum_{y=6}^{7} \beta_y Year_y + \sum_{r=8}^{11} \beta_r Source_r + \beta_{12}\text{Feed} + \sum_{p=13}^{14} Metaphyl_p + \sum_{p=15}^{16} Meta_p * Sex),$$

where all variables as are defined in Equations 5.8, 5.9, and 5.10 and Table 4.1.

The expectations of the signs and magnitudes of the coefficients are the same as for those in Equation 5.9. Again, the metaphylaxis coefficients are expected to be significant because one treatment should be more effective in keeping a given group of cattle healthy, and though there were no prior expectations for which treatment is most effective for this particular group, the performance model results indicate that overall Excede is more effective than Draxxin and that Draxxin is more effective than Micotil.

5.2 Statistical Analysis

Both ordered and binary logit models relate how independent variables affect the probability of the dependent variable occurring. Marginal probabilities are calculated for all continuous variables; a marginal probability is the change in the probability resulting from a one-unit change in an explanatory variable. Binary variables do not have marginal probabilities because they can only take one of two values, zero or one. Instead, probabilities are calculated for when the binary variable equals zero and when it equals one, where the difference between these calculated probabilities is of primary interest. These probabilities are calculated by holding continuous variables at their averages and the binary variables at their highest frequency (Bolte, 2007).

5.2.1 Castration Timing

The first binary logit model analyzes how each explanatory factor affects the probability of a calf needing to be treated at least once for BRD. Table 5.1 reports the estimates and probabilities for this model.

Table 5.1 Binary Logit Estimates for Equation 5.8 (Dependent Variable: *MorbidityYes*)

Variable	Parameter Estimate	Standard Error	P value	Probability That Morbidity = 1 (Treated)	
				Steer	**Bull**
Intercept	-3.821	0.605	<.0001		
Sex = 0		Default		0.0991	
Sex = 1	0.327	0.094	0.0005		0.1324
Season0		Default		0.0991	0.1324
Season1	1.231	0.163	<.0001	0.2735	0.3431
Season2	1.804	0.168	<.0001	0.4005	0.4811
Season3	0.939	0.171	<.0001	0.2195	0.2807
Year06		Default		0.0122	0.0169
Year07	2.184	0.185	<.0001	0.0991	0.1324
Year08	2.633	0.193	<.0001	0.1470	0.1929
Source0		Default		0.0991	0.1324
Source1	0.487	0.143	0.0006	0.1519	0.1990
Source2	1.395	0.482	0.0038	0.3074	0.3811
Source3	0.408	0.102	<.0001	0.1419	0.1866
Source4	0.003	0.237	0.9901	0.0993	0.1327
Feed = 0		Default		0.0991	0.1324
Feed = 1	-2.805	0.532	<.0001	0.0066	0.0091
				Marginal Impacts	
StartWt	-0.001	0.001	0.2881	-0.0001	-0.0001

Number of Observations = 3380
Log Likelihood = -1566

Contrary to expectations, starting weight does not affect the probability of needing to be treated for BRD; however the remaining variables, except one source variable, were significant. With all variables held at their averages or most frequent occurrence, bulls have over a 3% greater probability of needing treatment compared to steers. Steers arriving in the spring are least likely to get sick, at less than 10%, while those arriving in fall, early summer, and late summer have an approximately 12%, 17%, and 30%, respectively, greater probability of needing to be treated for BRD compared to spring arrivals. Bulls arriving in the spring are still least likely to get sick, at about 13%, with those arriving in fall, early summer, and late summer having approximately 15%, 21%, and 35%, respectively, greater probability of needing to be treated for BRD compared to spring arrivals. This makes sense as the greatest stress would occur during the hotter summer months of June, July, and August, which both the spring and fall arrivals would avoid, and early and late summer arrivals would be most subjected to. For no clearly identifiable reason, cattle arriving in 2007 and 2008 were much more likely to fall ill to BRD than those arriving in 2006. Of all sources, calves from Guthrie, KY (*Source2*) had the highest probability of getting sick at greater than 30%, while probabilities for the remaining sources were between 9% and 20%. Finally, those on a limit-feed diet have between a 9% and 13% lower probability of needing to be treated for BRD than those on an ad libitum diet. This could be due to different environmental and management factors that take place with these two different feeding regimens. When cattle are on a limit-feed diet, they are hungry at feeding time and all gather around the feed bunk at the same time whereas cattle with ad libitum access can eat anytime of the day. When cattle are sick, they do not eat, so it is easier to spot the sick ones when they hang back at feeding time. Therefore, the ill ones on the limit-feed diet should be treated quicker, thus limiting the spread of disease.

The second logit model estimated was an ordered logit model that looked at how the explanatory factors affected the probabilities of the number of times a calf will need to be treated for BRD. The estimates, probabilities, and marginal probabilities are reported in Table 5.2.

Table 5.2 Ordered Logit Estimates for Equation 5.9 (Dependent Variable: *Morbidity*; 0 = Not Treated for BRD to 3 = Treated Three Times for BRD)

Variable	Parameter Estimate	Standard Error	P value	0	1	2	3	0	1	2	3
Intercept†	-3.971	0.579	<.0001	**Steer Probabilities**				**Bull Probabilities**			
Limit 2†	1.702	0.052	<.0001								
Limit 3†	3.617	0.097	<.0001								
Sex = 0		Default		0.9080	0.0738	0.0154	0.0027				
Sex = 1	0.304	0.091	0.0008					0.8793	0.0963	0.0207	0.0037
Season0		Default		0.9080	0.0738	0.0154	0.0027	0.8793	0.0963	0.0207	0.0037
Season1	1.362	0.161	<.0001	0.7166	0.2161	0.0567	0.0105	0.6511	0.2599	0.0748	0.0142
Season2	1.823	0.163	<.0001	0.6145	0.2828	0.0861	0.0166	0.5406	0.3253	0.1118	0.0223
Season3	0.942	0.169	<.0001	0.7937	0.1610	0.0383	0.0069	0.7396	0.2001	0.0509	0.0094
Year06		Default		0.9891	0.0089	0.0017	0.0003	0.9853	0.0120	0.0023	0.0004
Year07	2.221	0.184	<.0001	0.9080	0.0738	0.0154	0.0027	0.8793	0.0963	0.0207	0.0037
Year08	2.682	0.192	<.0001	0.8617	0.1099	0.0241	0.0043	0.8214	0.1405	0.0323	0.0058
Source0		Default		0.9080	0.0738	0.0154	0.0027	0.8793	0.0963	0.0207	0.0037
Source1	0.547	0.138	<.0001	0.8511	0.1180	0.0262	0.0047	0.8084	0.1502	0.0351	0.0063
Source2	1.521	0.481	0.0016	0.6832	0.2388	0.0656	0.0123	0.6142	0.2831	0.0862	0.0166
Source3	0.537	0.098	<.0001	0.8523	0.1171	0.0260	0.0046	0.8098	0.1491	0.0348	0.0063
Source4	0.073	0.230	0.7513	0.9018	0.0788	0.0166	0.0029	0.8714	0.1024	0.0223	0.0040
Feed = 0		Default		0.9080	0.0738	0.0154	0.0027	0.8793	0.0963	0.0207	0.0037
Feed = 1	-2.776	0.531	<.0001	0.9937	0.0051	0.0010	0.0002	0.9915	0.0069	0.0013	0.0002
				Steer Marginal Probabilities				**Bull Marginal Probabilities**			
StartWt	-0.001	0.001	0.2909	9.84E-05	-7.7E-05	-1.8E-05	-3.2E-06	0.0001	-0.0001	0.0000	0.0000

Number of Observations = 3380

Log Likelihood = -2405

†The *Intercept* and *Limit* variables reported in "proc qlim" of SAS combine to form the category threshold values.

The results of the ordered logit model are nearly identical to the previous binary logit model in terms of significance. Starting weight is irrelevant in predicting how many times a calf will need to be treated for BRD, but everything else, except the same source variable, is important. Again, steers have a nearly 3% greater probability of never needing treatment, and bulls have a nearly 2.5% probability of requiring multiple treatments. Those arriving in the spring have the greatest probability, roughly 90% for both steers and bulls, of not needing treatment, while it is predicted that about 30% of those arriving in late summer will need to be treated once. Fall and early summer arrivals fall between the two extremes, with early summer arrivals having a higher probability of needing to be treated as well as needing to be treated more than once. In this model as well, again with no clearly identifiable reason as to why, calves arriving in 2006 have the greatest probability of remaining healthy at greater than 98% while 2007 and 2008 arrivals fall behind, with 2008 arrivals having the probability of needing treatment well into double digits. Most sources supply fairly healthy cattle with all but Guthrie, KY having probabilities of never needing treatment at greater than 80%. Guthrie, however, has the predicted probability that about a quarter will need treatment once and that another 7% of steers and 10% of bulls will need multiple treatments. Additionally, those on a limit-feed diet have a nearly 100% chance of never becoming sick while about 90% of those with ad libitum access will remain healthy, but about 7% of steers will require one treatment while nearly 10% of bulls will require one treatment.

5.2.2 Metaphylaxis Treatment

The next two logit models analyzed the efficacies of the three different metaphylaxis treatments. The first binary logit model estimated the probability of whether or not a calf would ever need treatment, irrespective of the number of times. The parameter estimates and calculated probabilities are presented in Table 5.3.

Table 5.3 Binary Logit Model Estimates for Equation 5.10 (Dependent Variable: *MorbidityYes*)

Variable	Parameter Estimate	Standard Error	P value	Probability That Morbidity = 1 (Treated)		
				Draxxin Predicted Value	**Micotil Predicted Value**	**Excede Predicted Value**
Intercept	-3.111	0.000	<.0001			
Sex = 0		Default		0.1051	0.2570	0.1969
Sex = 1	0.397	0.000	0.0020	0.1488	0.2879	0.2696
Season0		Default		0.1488	0.2879	0.2696
Season1	0.970	0.000	<.0001	0.3156	0.5161	0.4934
Season2	1.180	0.000	<.0001	0.3625	0.5681	0.5457
Season3	0.585	0.000	0.0103	0.2388	0.4206	0.3986
Year06		Default		0.0228	0.0512	0.0469
Year07	2.015	0.000	<.0001	0.1488	0.2879	0.2696
Year08	2.325	0.000	<.0001	0.1925	0.3555	0.3350
Source0		Default		0.1488	0.2879	0.2696
Source1	0.487	0.000	0.0008	0.2214	0.3968	0.3753
Source2	1.099	0.000	0.0238	0.3441	0.5483	0.5257
Source3	0.370	0.000	0.0004	0.2019	0.3691	0.3482
Source4	-0.371	0.000	0.1304	0.1076	0.2181	0.2030
Feed = 0		Default		0.1488	0.2879	0.2696
Feed = 1	-2.951	0.000	<.0001	0.0091	0.0207	0.0189
Metaphyl0		Default		0.1488		
Metaphyl1	1.080	0.000	<.0001		0.2879	
Metaphyl2	0.736	0.000	0.0030			0.2696
*Meta0*Sex*		Default		0.1488		
*Meta1*Sex*	-0.241	0.000	0.381		0.2879	
*Meta2*Sex*	0.012	0.000	0.956			0.2696
				Draxxin Marginal Impact	**Micotil Marginal Impact**	**Excede Marginal Impact**
StartWt	-0.002	0.000	0.0567	-0.0003	-0.0005	-0.0004

Number of Observations = 3380
Log Likelihood = -1539

The main significant variables in this model are the metaphylaxis variables. Calves administered Draxxin have a 15% probability of needing to be treated for BRD, while those administered Micotil and Excede have about a 13.5% and 12% greater chance of needing to be treated for BRD, respectively. Most other variables have the same relative interpretations in this model compared to the previous *MorbidityYes* model (Table 5.1), e.g., calves arriving in 2008 are still more likely to require BRD treatment than those arriving in 2007, and those arriving in 2007 are still more likely to require BRD treatment than those arriving in 2006. *Source4* is different; it is more statistically significant in this model, and now cattle coming from Glasgow, KY have a lower probability of needing treatment compared to those coming from Dickson, TN. The starting weight variable is statistically significant in this model as well and has a greater marginal impact on morbidity probability.

The second logit model estimated is an ordered logit model to estimate the probability of the number of times a calf will need treatment for BRD. The results of this model are shown in Table 5.4.

Table 5.4 Ordered Logit Model Estimates for Equation 5.11 (Dependent Variable: *Morbidity*; 0 = Not Treated for BRD to 3 = Treated Three Times for BRD)

Variable	Parameter Estimate	Standard Error	P value	0	1	2	3
Intercept†	-3.291	0.000	<.0001	**Draxxin Probabilities**			
Limit 2†	1.362	0.000	<.0001				
Limit 3†	2.749	0.000	<.0001				
Sex = 0		Default		0.9119	0.0639	0.0180	0.0061
Sex = 1	0.390	0.000	0.0021	0.8751	0.0896	0.0262	0.0091
Season0		Default		0.8751	0.0896	0.0262	0.0091
Season1	1.130	0.000	<.0001	0.6936	0.2048	0.0742	0.0275
Season2	1.251	0.000	<.0001	0.6673	0.2195	0.0823	0.0309
Season3	0.682	0.000	0.0024	0.7798	0.1527	0.0497	0.0177
Year06		Default		0.9809	0.0142	0.0037	0.0012
Year07	1.991	0.000	<.0001	0.8751	0.0896	0.0262	0.0091
Year08	2.421	0.000	<.0001	0.8200	0.1268	0.0394	0.0139
Source0		Default		0.8751	0.0896	0.0262	0.0091
Source1	0.540	0.000	0.0001	0.8033	0.1377	0.0436	0.0154
Source2	1.265	0.000	0.0103	0.6640	0.2213	0.0833	0.0314
Source3	0.506	0.506	<.0001	0.8090	0.1340	0.0421	0.0149
Source4	-0.298	0.000	0.2077	0.9042	0.0694	0.0197	0.0067
Feed = 0		Default		0.8751	0.0896	0.0262	0.0091
Feed = 1	-2.821	0.000	<.0001	0.9916	0.0063	0.0016	0.0005
Metaphyl0		Default		0.8751	0.0896	0.0262	0.0091
Metaphyl1	1.243	0.000	<.0001				
Metaphyl2	-0.031	0.000	0.8795				
*Meta0*Sex*		Default		0.8751	0.0896	0.0262	0.0091
*Meta1*Sex*	-0.268	0.000	0.301				
*Meta2*Sex*	-0.031	0.000	0.880				
				Draxxin Marginal Probabilities			
StartWt	-2.30E-03	-2.30E-03	0.0425	2.47E-04	-1.70E-04	-5.66E-05	-2.03E-05

Number of Observations = 3380
Log Likelihood = -2371
†The Intercept and Limit variables reported in "proc qlim" of SAS combine to form the category threshold values.

Table 5.4 Continued

Variable	Parameter Estimate	Standard Error	P value	0	1	2	3
Intercept†	-3.291	0.000	<.0001	**Micotil Probabilities**			
Limit 2†	1.362	0.000	<.0001				
Limit 3†	2.749	0.000	<.0001				
Sex = 0		Default		0.7491	0.1719	0.0580	0.0210
Sex = 1	0.390	0.000	0.0021	0.7255	0.1862	0.0647	0.0236
Season0		Default		0.7255	0.1862	0.0647	0.0236
Season1	1.130	0.000	<.0001	0.4606	0.3087	0.1610	0.0697
Season2	1.251	0.000	<.0001	0.4308	0.3164	0.1749	0.0780
Season3	0.682	0.000	0.0024	0.5720	0.2672	0.1151	0.0457
Year06		Default		0.9509	0.0361	0.0098	0.0033
Year07	1.991	0.000	<.0001	0.7255	0.1862	0.0647	0.0236
Year08	2.421	0.000	<.0001	0.6322	0.2382	0.0938	0.0359
Source0		Default		0.7255	0.1862	0.0647	0.0236
Source1	0.540	0.000	0.0001	0.6064	0.2511	0.1027	0.0399
Source2	1.265	0.000	0.0103	0.4271	0.3172	0.1766	0.0790
Source3	0.506	0.506	<.0001	0.6151	0.2468	0.0996	0.0385
Source4	-0.298	0.000	0.2077	0.7808	0.1521	0.0494	0.0176
Feed = 0		Default		0.7255	0.1862	0.0647	0.0236
Feed = 1	-2.821	0.000	<.0001	0.9780	0.0163	0.0043	0.0014
Metaphyl0		Default					
Metaphyl1	1.243	0.000	<.0001	0.7255	0.1862	0.0647	0.0236
Metaphyl2	-0.031	0.000	0.8795				
*Meta0*Sex*		Default					
*Meta1*Sex*	-0.268	0.000	0.301	0.7255	0.1862	0.0647	0.0236
*Meta2*Sex*	-0.031	0.000	0.880				
				Micotil Marginal Probabilities			
StartWt	-2.30E-03	-2.30E-03	0.0425	4.50E-04	-2.68E-04	-1.30E-04	-5.21E-05

Number of Observations = 3380

Log Likelihood = -2371

†The Intercept and Limit variables reported in "proc qlim" of SAS combine to form the category threshold values.

Table 5.4 Continued

Variable	Parameter Estimate	Standard Error	P value	0	1	2	3
Intercept†	-3.291	0.000	<.0001		**Excede Probabilities**		
Limit 2†	1.362	0.000	<.0001				
Limit 3†	2.749	0.000	<.0001				
Sex = 0		Default		0.8410	0.1128	0.0342	0.0120
Sex = 1	0.390	0.000	0.0021	0.7870	0.1482	0.0478	0.0170
Season0		Default		0.7870	0.1482	0.0478	0.0170
Season1	1.130	0.000	<.0001	0.5441	0.2792	0.1258	0.0509
Season2	1.251	0.000	<.0001	0.5140	0.2911	0.1379	0.0570
Season3	0.682	0.000	0.0024	0.6513	0.2281	0.0874	0.0331
Year06		Default		0.9643	0.0263	0.0070	0.0024
Year07	1.991	0.000	<.0001	0.7870	0.1482	0.0478	0.0170
Year08	2.421	0.000	<.0001	0.7061	0.1976	0.0704	0.0259
Source0		Default		0.7870	0.1482	0.0478	0.0170
Source1	0.540	0.000	0.0001	0.6829	0.2108	0.0774	0.0289
Source2	1.265	0.000	0.0103	0.5103	0.2924	0.1394	0.0578
Source3	0.506	0.506	<.0001	0.6908	0.2064	0.0750	0.0278
Source4	-0.298	0.000	0.2077	0.8327	0.1183	0.0362	0.0127
Feed = 0		Default		0.7870	0.1482	0.0478	0.0170
Feed = 1	-2.821	0.000	<.0001	0.9841	0.0117	0.0031	0.0010
Metaphyl0		Default					
Metaphyl1	1.243	0.000	<.0001				
Metaphyl2	-0.031	0.000	0.8795	0.7870	0.1482	0.0478	0.0170
*Meta0*Sex*		Default					
*Meta1*Sex*	-0.268	0.000	0.301				
*Meta2*Sex*	-0.031	0.000	0.880	0.7870	0.1482	0.0478	0.0170
					Excede Marginal Probabilities		
StartWt	-2.30E-03	-2.30E-03	0.0425	3.79E-04	-2.42E-04	-9.91E-05	-3.78E-05

Number of Observations = 3380

Log Likelihood = -2371

†The Intercept and Limit variables reported in "proc qlim" of SAS combine to form the category threshold values.

Again, the main significant variables of interest are the metaphylaxis variables. The model predicts that less than a quarter of the cattle administered Micotil will stay healthy throughout the receiving period while more than 85% of the cattle administered Draxxin should remain healthy. Excede-administered cattle fall in the middle with about 79% of bulls and 84% of steers remaining healthy. Only approximately 6% and 9% of Draxxin-treated steers and bulls, respectively, will require one treatment compared to about 11% and 15% of Excede-treated steers and bulls, respectively, and 17% and 18.5% of Micotil-treated steers and bulls, respectively. Furthermore, Micotil-treated steers are three times more likely to require multiple BRD treatments than Draxxin-treated steers, and Micotil-treated bulls are about 2.5 times more likely to require multiple BRD treatments than Draxxin-treated bulls. Relative to Draxxin-administered steers and bulls, Excede-administered steers and bulls are a little less than twice as likely to need multiple BRD treatments.

5.3 Economic Results

5.3.1 Castration Timing

The results of the morbidity models, specifically the ordered logit model, can be applied to the breakeven purchase prices and discounts found in Section 4.3.1. The breakeven purchase prices were found for four steers and four bulls, all of varying degrees of health (and different starting weights), but when purchasing these cattle there is no way to know for certain exactly which calves will remain healthy and which will require multiple treatments for BRD. Using the probabilities presented in Table 5.2, the average purchase prices or discounts can be calculated and are displayed for the typical calf arriving at 459 pounds, 400 pounds, and 500 pounds in Table 5.5, Table 5.6, and Table 5.7, respectively.

Taking into account the probabilities of a calf arriving at 459 pounds needing treatment for BRD, the average breakeven purchase price for a steer is $118.06/cwt and $113.37/cwt for a bull. Overall when taking into account poorer performance due to castration and a higher probability of needing treatment, bulls should be discounted, on average, $4.69/cwt relative to a steer. When the arrival weight drops to 400 pounds, the average breakeven purchase price for a steer is $126.42/cwt and $121.05/cwt for a bull. The average discount for bulls compared to steers is $5.37/cwt. When the arrival weight increases to 500 pounds, the average breakeven purchase prices for steers and bulls are $112.93/cwt and $108.73/cwt, respectively. The average discount for bulls relative to steers drops to $4.20/cwt.

As in Section 4.3.1, one would expect the discount to increase as starting weight increases as castration is a more significant stressor to heavier bulls, but the sex, starting weight interaction term was necessarily excluded from the model. Again, the price slide and greater cost per hundredweight for lighter calves may explain the narrowing of the discount with increased body weight.

Table 5.5 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 459 lbs

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
BE Purchase Price, $/cwt	$118.59	$114.42	$107.19	$102.40	$114.01	$110.25	$103.26	$98.34
Price Disc to BE, $/cwt		-$4.17	-$11.40	-$16.19	-$4.58	-$8.34	-$15.33	-$20.25
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt‡				-$0.53				-$5.22
Avg Purchase Price, $/cwt‡				$118.06				$113.37

†Base animal to which other animals are being compared
‡Calculated as a weighted average using the morbidity probabilities

Table 5.6 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 400 lbs

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
BE Purchase Price, $/cwt	$127.06	$121.95	$113.16	$107.01	$121.85	$117.12	$108.67	$102.16
Price Disc to BE, $/cwt		-$5.11	-$13.91	-$20.06	-$5.21	-$9.94	-$18.39	-$24.90
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt‡				-$0.65				-$6.01
Avg Purchase Price, $/cwt‡				$126.42				$121.05

† Base animal to which other animals are being compared
‡ Calculated as a weighted average using the morbidity probabilities

Table 5.7 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 500 lbs

	Steer				Bull			
	No Treat†	**1 Treat**	**2 Treat**	**3 Treat**	**No Treat**	**1 Treat**	**2 Treat**	**3 Treat**
BE Purchase Price, $/cwt	$113.39	$109.80	$103.34	$99.41	$109.31	$105.92	$99.85	$95.73
Price Disc to BE, $/cwt		-$3.58	-$10.05	-$13.98	-$4.08	-$7.46	-$13.53	-$17.65
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt‡				-$0.46				-$4.65
Avg Purchase Price, $/cwt‡				$112.93				$108.73

† Base animal to which other animals are being compared

‡ Calculated as a weighted average using the morbidity probabilities

5.3.2 Metaphylaxis Treatment

The results of the metaphylaxis treatment ordered logit morbidity model can be applied to the breakeven purchase prices and discounts found in Section 4.3.2. As before, the breakeven purchase prices were found for four steers and four bulls, all of varying degrees of health and administered three different metaphylaxis treatments on arrival, but when purchasing these cattle there is no way to know for certain exactly which calves will remain healthy and which will require multiple treatments for BRD. Based on the probabilities presented in Table 5.4, the average purchase prices or discounts can be calculated and are displayed for the typical calf arriving at 459 pounds in Table 5.8 (administered Draxxin on arrival), Table 5.9 (administered Micotil on arrival), and Table 5.10 (administered Excede on arrival).

Applying the morbidity probabilities to the previously calculated breakeven purchase prices and discounts, the average breakeven purchase prices for steers and bulls treated with Draxxin on arrival are \$113.57/cwt and \$109.18/cwt, respectively. When planning on using Draxxin as the metaphylaxis treatment, bulls need to be discounted, on average, \$4.39/cwt compared to steers. The average breakeven purchase prices for steers and bulls treated with Micotil on arrival are \$112.71/cwt and \$109.44/cwt, respectively. When planning on using Micotil as the metaphylaxis treatment, bulls only need to be discounted, on average, \$3.27/cwt relative to steers. The average breakeven purchase prices for steers and bulls treated with Excede on arrival are \$116.31/cwt and \$110.40/cwt, respectively. When planning on using Excede as the metaphylaxis treatment, bulls need to be discounted, on average, \$5.91/cwt relative to steers. The discounts for bulls are both higher and lower when examining metaphylaxis treatments than when examining just the effects of castration timing. These differences are a result of the disparity in performance between steers and bulls within each metaphylaxis treatment group. Comparing the discounts between the metaphylaxis treatments, steers need to be discounted $2.74/cwt and $3.60/cwt if Draxxin and Micotil, respectively, instead of Excede will be the selected treatment. For bulls, the discounts necessary to apply if using Draxxin and Micotil instead of Excede are $1.22/cwt and $0.96/cwt, respectively.

Like in Section 4.3.2, this indicates that Excede overcomes the increased dosage costs since each Micotil-treated animal requires a larger discount than its Excede-treated counterpart. Draxxin overcomes the increased dosage costs over Micotil only for steers. This is a result of the difference in performance advantages of Draxxin-treated steers and bulls relative to Micotil-treated steers and bulls in combination with the more than double dosage cost of Draxxin relative to Micotil. Draxxin-administered steers maintain a nearly four-tenths of a pound per day advantage over Micotil-administered steers at each successive BRD treatment, but Draxxin-administered bulls only maintain about a two-tenths of a pound per day advantage over Micotil-administered bulls.

Table 5.8 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 459 lbs and Administered Draxxin on Arrival

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
BE Purchase Price, $/cwt	$114.10	$110.39	$103.34	$98.51	$109.96	$105.93	$99.11	$94.71
Price Disc to BE, $/cwt		-$3.71	-$10.76	-$15.59	-$4.14	-$8.17	-$14.99	-$19.38
Morbidity Probabilities	91.19%	6.39%	1.80%	0.61%	87.51%	8.96%	2.62%	0.91%
Avg Disc, $/cwt‡				-$0.53				-$4.92
Avg Purchase Price, $/cwt‡				$113.57				$109.18

†Base animal to which other animals are being compared

‡Calculated as weighted average using morbidity probabilities

Table 5.9 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 459 lbs and Administered Micotil on Arrival

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
BE Purchase Price, $/cwt	$114.34	$110.58	$103.29	$98.23	$111.28	$107.22	$100.22	$95.73
Price Disc to BE, $/cwt		-$3.76	-$11.05	-$16.11	-$3.06	-$7.12	-$14.12	-$18.61
Morbidity Probabilities	74.91%	17.19%	5.80%	2.10%	72.55%	18.62%	6.47%	2.36%
Avg Disc, $/cwt‡				-$1.63				-$4.90
Avg Purchase Price, $/cwt‡				$112.71				$109.44

†Base animal to which other animals are being compared

‡Calculated as weighted average using morbidity probabilities

Table 5.10 Average Breakeven Purchase Prices and Discounts for the Typical Calf Arriving at 459 lbs and Administered Excede on Arrival

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
BE Purchase Price, $/cwt	$117.28	$113.63	$106.51	$101.94	$111.70	$107.99	$101.19	$96.72
Price Disc to BE, $/cwt		-$3.64	-$10.77	-$15.33	-$5.57	-$9.28	-$16.09	-$20.56
Morbidity Probabilities	84.10%	11.28%	3.42%	1.20%	78.70%	14.82%	4.78%	1.70%
Avg Disc, $/cwt‡				-$0.96				-$6.88
Avg Purchase Price, $/cwt‡				$116.31				$110.40

†Base animal to which other animals are being compared

‡Calculated as weighted average using morbidity probabilities

CHAPTER 6 - CARCASS QUALITY

6.1 Modeling

Another objective of this study is to examine whether or not castration and illness affect carcass quality. This is accomplished through the estimation of several OLS regressions and logit models in SAS. Since profitability is primary for most everyone, the main concern is the value of the carcass and factors that tend to increase or decrease its value. Price per hundredweight will be evaluated using the available carcass data, where the individual carcass characteristics will be linked back to the cattle during their time at the stocker unit. Therefore, the first step is to analyze how various factors in the backgrounding stage affect different carcass characteristics:

(6.1) $$Carcass\ characteristic = f\begin{pmatrix} sex, starting\ weight, arrival\ season, \\ source, morbidity\ status \end{pmatrix}.$$

Arrival year is not included because all cattle with available carcass data arrived in 2008. Summary statistics are presented in Table 6.1, and correlation coefficients of key variables are reported in Table 6.2.

Table 6.1 Summary Statistics for Carcass Dataset

Variable	Mean	Standard Deviation	Min	Max	Frequency	Percentage
StartWt (All)	**443.5**	**38.1**	**318**	**564**	**377**	**100%**
StartWt (Steers)	444.3	40.4	318	538	122	32%
StartWt (Bulls)	443.1	37.0	342	564	255	68%
Sex*StWt (All)	**299.7**	**209.8**	**0**	**564**	**377**	**100%**
*Sex*StWt (Steers)*	0.0	0.0	0	0	122	32%
*Sex*StWt (Bulls)*	443.1	37.0	342	564	255	68%
ReVaccWt (All)	**491.8**	**45.3**	**362**	**676**	**377**	**100%**
ReVaccWt (Steers)	499.2	52.7	362	676	122	32%
ReVaccWt (Bulls)	488.3	41.0	370	666	255	68%
RADG (All)	**4.8**	**2.4**	**-1.4**	**19.6**	**377**	**100%**
RADG (Steers)	5.5	2.8	-0.4	19.6	122	32%
RADG (Bulls)	4.5	2.1	-1.4	10.2	255	68%
EndWt (All)	**589.6**	**55.1**	**454**	**786**	**377**	**100%**
EndWt (Steers)	606.2	63.6	468	786	122	32%
EndWt (Bulls)	581.7	48.6	454	778	255	68%
ADG (All)	**3.2**	**0.9**	**0.0**	**7.6**	**377**	**100%**
ADG (Steers)	3.5	0.9	1.6	7.6	122	32%
ADG (Bulls)	3.0	0.8	0.0	4.9	255	68%
Sex						
Steers (Sex = 0)					122	32%
Bulls (Sex = 1)					255	68%
Arrival Season						
Season0					190	50%
Season1					187	50%
Arrival Year						
Year08					377	100%
Source						
Source0					248	66%
Source3					129	34%
Morbidity						
Morbidity0					260	69%
Morbidity1					67	18%
Morbidity2					39	10%
Morbidity3					9	2%
Morbidity4					2	1%

Table 6.1 Continued

Variable	Mean	Standard Deviation	Min	Max	Frequency	Percentage
Carcass Characteristics						
HCW	850.10	75.22	628.00	1063.00	377	100%
HCW2	728318.20	128447.29	394384.00	1129969.00	377	100%
REA	13.41	1.57	8.77	18.09	376	100%
BF	0.43	0.15	0.00	1.07	376	100%
DaysToMkt	319.32	30.33	285.00	357.00	377	100%
MarblingScore†	362.39	84.93	190.00	620.00	376	100%
PriceCWT	130.82	5.71	87.44	144.12	377	100%
ChoicePlus						
Quality Grade Standard or Select (ChoicePlus = 0)					96	25%
Quality Grade Choice or Prime (ChoicePlus = 1)					281	75%
CAB						
Did not qualify for CAB (CAB = 0)					302	80%
Qualified for CAB (CAB = 1)					75	20%
NAB						
Did not qualify for NAB (NAB = 0)					339	90%
Qualified for NAB (NAB = 1)					38	10%
Discount						
Had no discount characteristics (Discounts = 0)					371	98%
Exhibited discount characteristics (Discounts = 1)					6	2%
Quality Grade						
QualityGrade1					4	1%
QualityGrade2					92	24%
QualityGrade3					277	73%
QualityGrade4					4	1%
Yield Grade						
YieldGrade1					23	6%
YieldGrade2					149	40%
YieldGrade3					175	46%
YieldGrade4					30	8%

Number of Observations = 377

†*MarblingScores* reported as Traces 100, Slight 200, Small 300, Modest 400, Moderate 500, Slightly Abundant 600

Table 6.2 Correlation Coefficients for Carcass Model Variables

Variable	*HCW*	*REA*	*BF*	*YieldGrade*	*QualityGrade*	*PriceCWT*	*DaysToMkt*
HCW	–						
REA	0.432	–					
BF	0.095	-0.269	–				
YieldGrade	0.147	-0.601	0.595	–			
QualityGrade	0.014	-0.156	0.159	0.182	–		
PriceCWT	-0.250	-0.086	0.017	0.059	0.525	–	
DaysToMkt	0.429	0.277	-0.093	-0.106	-0.107	-0.347	–

Cattle carcasses are assigned two different grades: a quality grade and a yield grade. These grades are composite evaluations of factors that affect palatability of meat and cutability of the carcass, respectively. The four USDA quality grades (QG), from worst to best, are Standard, Select, Choice, and Prime. Quality grades are based on degree of marbling and degree of maturity. Marbling scores range from 00 (practically devoid) to 900 (abundant), where the higher the marbling score, the higher the quality grade. Maturities range from A to E, with A being the youngest and most desirable. Yield grades (YG) are on a scale from 1 to 5, with 1 denoting the highest cutability or having the highest yielding carcass and 5 denoting the lowest cutability or having the lowest yielding carcass. Yield grades are calculated by evaluating external fat, i.e., backfat (BF), hot carcass weight (HCW), ribeye area (REA), and the amount of kidney, pelvic, and heart fat (%KPH). Less BF, higher HCW, more REA, and less %KPH result in higher cutability (Hale, Goodson, and Savell).

Hot carcass weight, ribeye area, backfat, yield grade, marbling score, quality grade, two brands of beef (CAB and NAB), and discounts (hard bone, dark cutter, and age 30 months) were the carcass characteristics with available data. Therefore, four OLS models, four binary logit models and two ordered logit model were estimated for these carcass characteristics:

(6.2) $$HCW = \alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m,$$

(6.3) $$REA = \alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m,$$

(6.4) $$BF = \alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m,$$

(6.5) $$YieldGrade_d = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m),$$

(6.6) $$MarblingScore = \alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m,$$

(6.7) $$ChoicePlus = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m),$$

(6.8) $$QualityGrade_q = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m),$$

(6.9) $$CAB = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{7} \beta_m \, Morbidity_m),$$

(6.10) $$NAB = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r + \sum_{m=5}^{6} \beta_m \, Morbidity_m), and$$

(6.11) $Discounts = F(\alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Season_s + \beta_4 Source_r)$.

Not all seasons and sources are represented in these models, therefore,

Season$_s$ = a set of dummy variables for arrival season (*s* = spring and early summer; default = spring)

Source$_r$ = a set of dummy variables for lot source (*r* = Dickson, TN and Sweetwater, TN and additional pick-ups; default = Dickson, TN)

YieldGrade$_d$ = a set of dummy variables for yield grade (*d* = YG1, YG2, YG3, YG4; default = YG1)

QualityGrade$_q$ = a set of dummy variables for quality grade (*q* = Standard, Select, Choice, Prime; default = Standard)

and all other variables and subscripts are as defined in Table 4.1.

In the *HCW*, *REA*, *MarblingScore*, *ChoicePlus*, *QualityGrade*, *CAB,* and *NAB* models, higher numbers are desired for the dependent variables, and in the *BF*, *YieldGrade,* and *Discounts* models, lower numbers are desired for the dependent variables. In accordance with the reviewed studies (Klosterman et al., 1954; Champagne et al., 1969; Field, 1971; Landon, Hedrick, and Thompson, 1978; Seideman et al., 1982; Gregory and Ford, 1983; Worrell, Clanton, and Calkins, 1987; Schoonmaker et al., 2002; Lents et al., 2006), the sex variable, if significant, is expected to be positive in the *HCW* and *REA* models and negative in the *BF*, *YieldGrade*, *MarblingScore*, *ChoicePlus*, *QualityGrade*, *CAB*, and *NAB* models. Starting weight might only be significant in the *HCW* model and is expected to be positive. Seasons and sources are not predictable, but cattle arriving in the hotter summer months and from “poorer” sources should have decreased gain and increased morbidity and thus have smaller HCW, REA, BF, marbling scores and quality grades, and higher yield grades, as well as fewer grading Choice or

Prime or qualifying for CAB or NAB. Finally, those that are morbid are expected to have worse carcasses than those that are not, with cattle requiring multiple treatments having worse carcasses than those just needing one treatment. Therefore, the *Morbidity3* variable should have a larger impact than the *Morbidity2* variable, and likewise, the *Morbidity2* variable should have a greater impact than the *Morbidity1* variable. All the morbidity 1, 2, 3, and 4 variables are expected to be positive in the yield grade model and negative in all the other models because morbidity should inhibit fat deposition and decrease HCW and REA. Furthermore, morbidity and sex may be the only variables that consistently affect the probability of discount characteristics occurring where the morbidity and sex variables are both expected to be positive since excessive morbidity and late-castration might increase the probability of having a carcass exhibit hard bone, dark cutter, or age 30 months. To be complete, the *Discounts* model was also looked at but could not be estimated with this dataset.

The next model to estimate is the pricing model with price per hundredweight (cwt) being the dependent variable. This model will look at what factors are important in determining carcass price as well as how they affect price. Market timing also affects cattle prices, and arrival season can be included to capture seasonality in prices. Thus, the conceptual model is:

(6.12) $PriceCWT = f(season, carcass\ characteristics)$.

There were several characteristics to determine both carcass quality and cutability. Several different configurations of the pricing model were estimated, without overestimating the model by including redundant characteristics. The final pricing model estimated and used is the following:

$$(6.13)\quad PriceCWT = \alpha + \beta_1 Season_s + \beta_2 HCW + \beta_3 HCW2 + \beta_4 REA + \beta_5 BF + \sum_{q=6}^{8} \beta_q\, QualityGrade_q + \beta_9 CAB + \beta_{10} NAB + \beta_{11} Discount,$$

where all seasons are not represented in this model; therefore,

$Season_s$ = a set of dummy variables for arrival season (s = spring and early summer; default = spring)

and all other variables are defined for Equations 6.2-6.11 and in Table 4.1.

Instead of including yield grade directly in the model, the available individual characteristics determining yield grade were included. Hot carcass weight and ribeye area are expected to be positive since both larger HCW and REA increase cutability. Likewise, less backfat increases cutability, thus *BF* should be negative. Based on resulting significance when estimating models using one or the other, it was determined to use the discrete quality grades instead of the continuous marbling scores. Using USDA Standard as the base, all other grades should have premiums, with Choice having a greater premium than Select and Prime a greater premium than Choice. CAB and NAB are both higher quality brands of beef, with CAB having more stringent qualifications and greater consumer awareness, thus both should exhibit premiums with CAB having the higher premium. Finally, discounts are self-explanatory, and the coefficient on this variable should be negative.

Additionally, though not affecting carcass quality, the amount of time on feed until slaughter is an important economic factor in feeding out cattle. So in addition to examining how the experiences of a calf during its backgrounding phase affected its carcass characteristics, a model was developed to look at the relationship between those factors and the days from arrival at the stocker unit until kill:

(6.14) $DaysToMkt = f(sex, starting\ weight, arrival\ season, source, morbidity\ status)$

with the empirical model being:

$$DaysToMkt = \alpha + \beta_1 Sex + \beta_2 StartWt + \beta_3 Sex * StWt + \beta_4 Season_s + \beta_5 Source_r + \sum_{m=6}^{8} \beta_m Morbidity_m \quad (6.15)$$

where all seasons and sources are not represented in this model, therefore,

Season$_s$ = a set of dummy variables for arrival season (*s* = spring and early summer; default= spring)

Source$_r$ = a set of dummy variables for lot source (*r* = Dickson, TN and Sweetwater, TN and additional pick-ups; default = Dickson, TN)

and all other variables are as defined in Table 4.1.

Again, after reviewing past research, some of these variables may not be significant in explaining the number of days on feed before slaughter, but due to the conflicting nature of prior results, it was decided to determine their significance in this dataset as well. Sex could be negative or positive because bulls have been found to be more feed efficient, though this is not necessarily true for late-castrated steers, and fat deposition is slower in bulls. Starting weight would also be positive; cattle starting out heavier would presumably be further along in development, enabling them to finish faster than cattle arriving at lighter weights. For the same reasons as before, seasons and sources are ambiguous but could potentially affect the days to slaughter. Morbidity is expected to prolong time on feed, thus having positive coefficients and larger magnitudes for the multiple treatment morbidity variables. Basically, this model is similar to the performance models, only looking at gain from another angle.

6.2 Statistical Analysis

In analyzing the multiple carcass characteristic models, only the hot carcass weight model had any statistical significance with the model being able to explain 14% of the variability in HCW. The statistical insignificance of the models indicates that the explanatory variables examined, specifically sex and morbidity, have little, if any, effect on carcass quality or cutability. The results of the HCW model are presented in Table 6.3. All other carcass characteristic model results are reported in Appendix A.

Table 6.3 *HCW* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	704.237	43.220	16.29	<.0001
Sex	-10.900	7.737	-1.41	0.1597
StartWt	0.396	0.095	4.16	<.0001
Arrival Season (Default = Season0)				
Season1	-35.468	7.449	-4.76	<.0001
Source (Default = Source0)				
Source3	-5.116	7.699	-0.66	0.5068
Morbidity (Default = Morbidity0)				
Morbidity1	3.736	9.611	0.39	0.6977
Morbidity2	-25.948	12.416	-2.09	0.0373
Morbidity3	-50.448	24.057	-2.10	0.0367

Number of Observations = 377
RMSE = 69.645
Adj. R^2 = 0.1426

Starting weight and season are significant at the 1% level. As would be expected, those that arrived heavier had heavier hot carcass weights; a calf that started 100 pounds heavier would have a HCW with an additional 39.6 pounds. Furthermore, cattle arriving in early summer have hot carcass weights that are 35 pounds lighter than those arriving in spring. Of the morbidity variables, only *Morbidity2* and *Morbidity3* were statistically significant, decreasing HCW by 26 and 50 pounds, respectively. Finally, and contrary to previous research, late-castrated steers tended to have lower HCW.

The estimated parameter coefficients for the *PriceCWT* model are shown in Table 6.4. The model explains 65% of the variability in price/cwt with all but one variable being statistically significant at the 1% level.

Table 6.4 *PriceCWT* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	13.569	16.389	0.83	0.4083
CAB	5.096	0.476	10.71	<.0001
NAB	2.142	0.611	3.51	0.0005
HCW	0.234	0.038	6.10	<.0001
HCW2	-1.509E-04	2.239E-05	-6.74	<.0001
REA	0.394	0.134	2.94	0.0035
BF	0.273	1.262	0.22	0.8288
Discounts	-6.635	1.758	-3.77	0.0002
Arrival Season (Default = Season0)				
Season1	-1.308	0.364	-3.59	0.0004
Quality Grade (Default = QualityGrade1)				
QualityGrade2	20.603	2.151	9.58	<.0001
QualityGrade3	23.157	2.131	10.87	<.0001
QualityGrade4	36.634	2.703	13.55	<.0001

Number of Observations = 376
RMSE = 3.345
Adj. R^2 = 0.6573

All the coefficients of the significant variables exhibited the expected signs. Furthermore, CAB had a nearly $3/cwt premium over NAB. The CAB premium is twice the national average of $2.50/cwt (U.S. Department of Agriculture, 2009). Prime commands nearly $13.50/cwt more than Choice, Choice, $2.55/cwt more than Select, and Select, $20.60 more than

Standard. The premiums of Prime relative to Choice and Select relative to Standard differ from the national averages but do fall within the reported ranges. The discount of Select relative to Choice is both less than the average and the range minimum (U.S. Department of Agriculture, 2009). Exhibition of any discount characteristic, i.e., hard bone, dark cutter, or age 30 months, drops the price/cwt by $6.64. This discount is much smaller than the national averages (U.S. Department of Agriculture, 2009). Additionally, cattle arriving at the stocker unit in spring and slaughtered in the winter (December-February) received $1.31/cwt more than their counterparts arriving in early summer and slaughtered in spring (March and April).

Parameter estimates for the *DaysToMkt* model are presented in Table 6.5. The model explains nearly 60% of the variability in the number of days to market. All variables except morbidity were statistically significant, and all significant variables were significant at the 1% level.

Table 6.5 *DaysToMarket* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	423.452	19.811	21.37	<.0001
Sex	-65.061	24.882	-2.61	0.0093
StartWt	-0.183	0.044	-4.12	<.0001
Sex_StWt	0.150	0.056	2.69	0.0076
Arrival Season (Default = Season0)				
Season1	-44.910	2.115	-21.23	<.0001
Source (Default = Source0)				
Source3	-5.907	2.176	-2.71	0.0069
Morbidity (Default = Morbidity0)				
Morbidity1	3.436	2.717	1.26	0.2067
Morbidity2	-1.818	3.509	-0.52	0.6048
Morbidity3	-0.947	6.801	-0.14	0.8893

Number of Observations = 377

RMSE = 19.658

Adj. R^2 = .5798

Cattle arriving at heavier weights reached market readiness first; for each extra one hundred pounds at arrival, early-castrated steers reached their targeted end 18 days sooner, and for each extra one hundred pounds at arrival, late-castrated steers reached their targeted end three days sooner. Late-castrated steers castrated at weights greater than 434 pounds required more days to market than early-castrated steers while those castrated at less than 434 pounds required less days to market. Early summer arrivals spent 45 less days on feed than spring arrivals. Additionally, cattle from Sweetwater, TN and additional pick-ups spent nearly six less days on feed than those from Dickson, TN.

6.3 Economic Results

Thus far, breakeven purchase prices and discounts have been calculated only if the cattle were owned for a short backgrounding period of 44 days. Retained ownership is a possibility, and further calculations were made utilizing the hot carcass weight (Table 6.3) and days to market results (Table 6.5). To determine how much the late-castrated, morbid steers would need to be discounted if ownership was retained through slaughter, several estimates and assumptions were needed.

First, the normal range for dressing percentage for steers and heifers is 55-67%, with 62% being the average for Choice steers and heifers (Beef Cattle Grading). Also, an estimated pencil shrink was needed. According to Lardy's "Cattleman's Guide to Feedlot Lingo" (1999), pencil shrink for fed cattle is usually 4% which would agree with Gill, Barnes, and Lalman's report of 5.5% shrink after eight hours in a moving truck. The cost of gain in the feedlot phase was also estimated to be $74/cwt for 332 days to market, using feed cost of gain calculations that used a ration charge/ton of $160 and yardage charge/head of $0.15 (Waggoner, 2009), and interest of

7%. There was an estimated $1 increase in cost of gain per hundredweight for each additional week on feed (Dhuyvetter, 2009). Finally, the cash selling price of the live animal was estimated at $88.10/cwt using the live cattle futures price of $89.85/cwt found on www.BeefBasis.com on October 16, 2009 and the basis of -$1.75 for the week ending December 25 found on www.agmanager.info ("December CME," 2009).

The cost/head from the backgrounding period, i.e., *Cost, $/hd* plus any additional costs and potential mortality costs, was carried over and identified as *Cost: Phase 1, $/hd*. Live slaughter weight was calculated using the assumed dressing percentage and shrink of 62% and 4%, respectively, and an estimated hot carcass weight using the results (Table 6.3) from Equation 6.2. *Stocker End Wt* is the calculated ending weight used earlier and was calculated using the projected ADG and DOF for the backgrounding period. The weight difference is the stocker end weight subtracted from the slaughter weight. Days to market were calculated using the results (Table 6.5) from Equation 6.15. Average daily gain in phase 2, i.e., the feedlot phase, was determined by taking the weight difference divided by days to market minus the DOF in the backgrounding period. The *COG, $/cwt* was entered as previously defined, and the *Cost: Phase 2, $/hd* is the *COG, $/cwt* multiplied by the weight difference. The costs/head from phases 1 and 2 were totaled to arrive at the total cost/head. Revenue in $/head is slaughter weight multiplied by the cash price. *Revenue - Cost, $/hd* is revenue minus the *Total Cost, $/head*; this number was then divided by the original starting weight and multiplied by 100 to arrive at the breakeven purchase price for the stocker calf. Discounts are found by subtracting the breakeven purchase price of the discounted animal from the base animal, i.e., the healthy steer. Average breakeven purchase prices and price discounts are found by calculating the weighted average of each multiplied by the proper morbidity probabilities found in Table 5.2. The breakeven purchase prices and discounts and average breakeven purchase prices and discounts for retaining ownership through slaughter are presented for the typical calf arriving in spring 2007 from Dickson, TN at 459 pounds and put on an ad libitum diet (Table 6.6), the typical calf arriving at 400 pounds (Table 6.7), and the typical calf arriving at 500 pounds (Table 6.8).

When retaining ownership through slaughter of cattle arriving at 459 pounds, the average breakeven purchase price for steers is $114.28/cwt and $107.51/cwt for bulls, for an average discount of $6.77/cwt for bulls relative to steers. When the starting weight falls to 400 pounds, the average breakeven purchase price for steers is $115.62/cwt and $110.71/cwt for bulls, resulting in an average discount of $4.91/cwt for bulls compared to steers. When the starting weight increases to 500 pounds, the average breakeven purchase price for steers is $113.15/cwt compared to $105.60/cwt for bulls. The average discount increases to $7.55/cwt for bulls relative to steers.

The average discount of bulls relative to steers is positively correlated with starting weight as would be expected. Castration initially diminishes performance and increases susceptibility to disease, more so with heavier bulls than lighter bulls. Late-castration of bulls greater than 434 pounds increases the time to market readiness. These factors would explain both the necessary discounts for bulls and the larger discounts for bulls arriving at heavier weights.

Table 6.6 Average Breakeven Purchase Prices and Price Discounts for Typical Calf Arriving at 459 lbs, Retaining Ownership Through Slaughter

	Steer				Bull			
	No Treat†	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Cost: Phase 1, $/hd	$117.66	$125.41	$139.71	$134.07	$129.31	$135.22	$147.48	$142.04
Slaughter Wt	1372.17	1377.96	1331.99	1294.06	1355.29	1361.08	1315.12	1277.18
Stocker End Wt	620.42	601.16	570.39	528.83	604.85	585.59	554.82	513.27
Wt Difference	751.75	776.80	761.60	765.22	750.44	775.49	760.29	763.91
Days To Mkt	339.45	339.45	339.45	339.45	343.21	343.21	343.21	343.21
ADG in Phase 2	2.54	2.63	2.58	2.59	2.51	2.59	2.54	2.55
Cost of Gain, $/cwt	$75.00	$75.00	$75.00	$75.00	$75.65	$75.65	$75.65	$75.65
Cost: Phase 2, $/hd	$563.81	$582.60	$571.20	$573.92	$567.71	$586.65	$575.16	$577.90
Total Cost, $/hd	$681.47	$708.00	$710.91	$707.99	$697.02	$721.87	$722.64	$719.94
Revenue, $/hd	$1,208.88	$1,213.98	$1,173.49	$1,140.06	$1,194.01	$1,199.11	$1,158.62	$1,125.20
Revenue-Cost, $/hd	$527.41	$505.98	$462.58	$432.07	$497.00	$477.24	$435.98	$405.25
BE Purchase Price, $/cwt	$114.90	$110.23	$100.78	$94.13	$108.28	$103.97	$94.98	$88.29
Price Disc to BE, $/cwt		-$4.67	-$14.12	-$20.77	-$6.63	-$10.93	-$19.92	-$26.61
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt‡				-$0.62				-$7.39
Avg Purchase Price, $/cwt‡				$114.28				$107.51

† Base animal to which other animals are being compared

‡ Calculated as a weighted average using the morbidity probabilities

Table 6.7 Average Breakeven Purchase Prices and Price Discounts for Typical Calf Arriving at 400 lbs, Retaining Ownership Through Slaughter

	Steer				Bull			
	No Treat[†]	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Cost: Phase 1, $/hd	$119.09	$126.82	$141.10	$135.45	$130.01	$135.87	$148.08	$142.54
Slaughter Wt	1335.96	1341.74	1295.78	1257.84	1319.08	1324.86	1278.90	1240.97
Stocker End Wt	563.90	544.64	513.87	472.31	548.33	529.07	498.30	456.75
Wt Difference	772.06	797.10	781.91	785.53	770.74	795.79	780.60	784.22
Days To Mkt	350.25	350.25	350.25	350.25	345.16	345.16	345.16	345.16
ADG in Phase 2	2.52	2.60	2.55	2.57	2.56	2.64	2.59	2.60
Cost of Gain, $/cwt	$76.75	$76.75	$76.75	$76.75	$76.00	$76.00	$76.00	$76.00
Cost: Phase 2, $/hd	$592.55	$611.78	$600.12	$602.89	$585.77	$604.80	$593.25	$596.01
Total Cost, $/hd	$711.64	$738.60	$741.22	$738.34	$715.77	$740.67	$741.33	$738.55
Revenue, $/hd	$1,176.98	$1,182.07	$1,141.58	$1,108.16	$1,162.11	$1,167.21	$1,126.71	$1,093.29
Revenue-Cost, $/hd	$465.34	$443.48	$400.36	$369.82	$446.33	$426.54	$385.38	$354.74
BE Purchase Price, $/cwt	$116.33	$110.87	$100.09	$92.45	$111.58	$106.63	$96.34	$88.69
Price Disc to BE, $/cwt		-$5.47	-$16.24	-$23.88	-$4.75	-$9.70	-$19.99	-$27.65
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt[‡]				-$0.72				-$5.63
Avg Purchase Price, $/cwt[‡]				$115.62				$110.71

[†] Base animal to which other animals are being compared

[‡] Calculated as a weighted average using the morbidity probabilities

Table 6.8 Average Breakeven Purchase Prices and Price Discounts for Typical Calf Arriving at 500 lbs, Retaining Ownership Through Slaughter

	Steer				Bull			
	No Treat[†]	1 Treat	2 Treat	3 Treat	No Treat	1 Treat	2 Treat	3 Treat
Cost: Phase 1, $/hd	$116.65	$124.40	$138.71	$133.10	$128.78	$134.69	$147.00	$141.62
Slaughter Wt	1397.34	1403.12	1357.16	1319.22	1380.46	1386.25	1340.28	1302.35
Stocker End Wt	659.70	640.44	609.67	568.11	644.13	624.87	594.10	552.54
Wt Difference	737.64	762.69	747.49	751.11	736.33	761.37	746.18	749.80
Days To Mkt	331.95	331.95	331.95	331.95	341.85	341.85	341.85	341.85
ADG in Phase 2	2.56	2.65	2.60	2.61	2.47	2.56	2.51	2.52
Cost of Gain, $/cwt	$74.00	$74.00	$74.00	$74.00	$75.50	$75.50	$75.50	$75.50
Cost: Phase 2, $/hd	$545.85	$564.39	$553.15	$555.82	$555.93	$574.84	$563.37	$566.10
Total Cost, $/hd	$662.50	$688.79	$691.86	$688.92	$684.70	$709.53	$710.37	$707.73
Revenue, $/hd	$1,231.05	$1,236.15	$1,195.66	$1,162.24	$1,216.18	$1,221.28	$1,180.79	$1,147.37
Revenue-Cost, $/hd	$568.55	$547.36	$503.80	$473.31	$531.48	$511.75	$470.42	$439.64
BE Purchase Price, $/cwt	$113.71	$109.47	$100.76	$94.66	$106.30	$102.35	$94.08	$87.93
Price Disc to BE, $/cwt		-$4.24	-$12.95	-$19.05	-$7.41	-$11.36	-$19.63	-$25.78
Morbidity Probabilities	90.80%	7.38%	1.54%	0.27%	87.93%	9.63%	2.07%	0.37%
Avg Disc, $/cwt[‡]				-$0.56				-$8.11
Avg Purchase Price, $/cwt[‡]				$113.15				$105.60

[†] Base animal to which other animals are being compared

[‡] Calculated as a weighted average using the morbidity probabilities

CHAPTER 7 - CONCLUSIONS

This thesis analyzes how castration timing affects performance, morbidity, and carcass quality. Breakeven purchase prices and price discounts and averages thereof were calculated for the short backgrounding period and for retaining ownership through slaughter. It also examines how three metaphylaxis drugs impact performance and morbidity. Breakeven purchase prices and price discounts and averages thereof were also calculated for the same backgrounding period.

In summary, all explanatory variables studied, i.e., sex, starting weight, arrival season and year, source, morbidity, and feed access significantly affect performance as measured by average daily gain. As would be expected, cattle arriving as bulls and those that require treatment for bovine respiratory disease (BRD) exhibit decreased daily gains relative to early-castrated, healthy steers. Late-castrated steers have decreased gains of a little more than a third of a pound per day throughout the entire receiving trial. This is consistent with previous studies finding decreased gains between 0.02 and 0.682 lbs/day (Wierbicki et al., 1995; Berry et al., 2001; Ratcliff et al., 2005; Duff and Galyean, 2007). Castration was also found to have greater effects closer to the time of castration, with newly-castrated steers gaining 0.75 pounds less per day during the time from arrival to revaccination, in line with Ratcliff et al. (2005) finding a difference of 1.94 lbs/day in the first seven days post arrival. This shows that cattle arriving as steers maintain a performance advantage throughout the entire receiving trial, even though cattle arriving as bulls exhibit compensatory gain. Average daily gains used for this analysis are higher than what typically might be expected for a receiving period. All weights used are actual shrunk weights as weighed and recorded by the K-State Stocker Unit; therefore cattle are able to exhibit greater than expected gains. Furthermore, results were generally not sensitive to different shrink assumptions.

Morbid cattle exhibited diminished gains of 0.4, 1.1, and 2.1 lbs/day (Table 4.5), dependent upon how many times they were treated. These findings are also consistent with prior research that show gains of 0.01 and 0.55 less pounds per day for morbid cattle, without distinguishing between number of treatments (Gardner et al., 1999; Stovall et al., 2000). Additionally Gardner et al. (1999) found that cattle treated more than once put on one less pound per day than cattle treated just once. Morbidity was also found to be significant in the timeframe from arrival to revaccination and to have a greater impact on daily gains during this time period as well. This indicates that compensatory gain occurs for morbid cattle as well as newly-castrated steers throughout the receiving trial.

With the decreased performance of late-castrated and morbid steers, these animals need to be discounted at purchase in order to breakeven. Based on market conditions in 2009, the breakeven purchase price of average arrival steers ranged from $102.40/cwt to $118.59/cwt. A steer that is expected to be treated for BRD once needs to be discounted $4.17/cwt, $11.40/cwt if expected to be treated twice, and $16.19/cwt if expected to be treated three times. The breakeven purchase price of bulls ranged from $98.34/cwt to $114.01/cwt. A bull with no expected health problems should be discounted $4.58/cwt compared to a “healthy” steer. Bulls that are expected to be treated once, twice, and three times for BRD should be discounted $8.34/cwt, $15.33/cwt, and $20.25/cwt, respectively, relative to a comparable “healthy” steer.

The morbidity logit models showed that late-castrated steers have a 3.3% greater probability of needing treatment for BRD than early-castrated steers. Other studies found that bulls castrated on arrival had greater incidences of morbidity and that more bulls require treatment and more multiple treatments compared to steers (Ratcliff et al., 2005; Duff and Galyean, 2007).

The breakeven purchase prices and discounts are useful, but how does one know how much to discount an animal based on morbidity expectations? Given that it is not possible to determine at purchase exactly how many times a calf will require treatment for BRD, the probabilities of getting sick as estimated by the ordered logit model are used to calculate the average discount to apply to a steer and to a bull relative to that of a steer that never falls ill to a respiratory ailment. The breakeven purchase price of a steer that will remain healthy is $118.59/cwt. Anticipating BRD morbidity, the average steer needs to be discounted $0.53/cwt for a purchase price of $118.06/cwt. For a bull, the average purchase price is $113.37/cwt, and the price discount relative to the “healthy” steer is $5.22/cwt. This results in an average price discount of $4.69/cwt for bulls relative to steers when taking into account the probabilities of both bulls and steers needing treatment for BRD. This discount to apply to bulls is consistent with model-estimated price differences found in other studies: discounts of $5.19/cwt in the spring and $5.91/cwt in the fall for 550-lb bulls relative to 550-lb steers (Schulz et al., 2009) and discounts from $4.30/cwt to $5.43/cwt, with an average of $4.76/cwt, for bull calves and mixed gender lots relative to steers (Ward, Ratcliff, and Lalman, 2005). Smith et al. (2000) found slightly smaller discounts in prices for bulls relative to steers: $3.56/cwt in 1997 and $2.24/cwt in 1999.

Timing of castration and morbidity could also ultimately affect carcass quality, yet this research indicates that castration timing and morbidity do not affect carcass quality. Castration timing was found to significantly affect the days to market but only showed a tendency to affect hot carcass weight. Bulls castrated beyond 434 pounds required more days on feed to reach market readiness. Though no research was found discussing days on feed for early- and late-castration, bulls required more days on feed to market because they were slower in reaching the optimum fat endpoint (Seideman et al., 1982; Schoonmaker et al., 2002). Bulls castrated prior to 434 pounds probably do not exhibit this problem since they are castrated before the hormones begin to affect fat deposition in the growing phase. Contrary to the increased days on feed, late-castrated steers in this study actually tended to have smaller hot carcass weights. Most studies find that bulls, not late-castrated steers, have significantly higher hot carcass weights than steers (Seideman et al., 1982; Schoonmaker et al., 2002). Perhaps the results here regarding hot carcass weights are different because all bulls are castrated on arrival at relatively light weights, thus castration diminishes gain but occurs early enough so as not to significantly impede intramuscular fat deposition. If intramuscular fat deposition were severely impeded, then days on feed for late-castrated steers would probably have been even greater. This lack of significance would, however, be consistent with some studies (Klosterman et al., 1954; Lents et al., 2006) that found no negative effects of late-castration on measured carcass traits.

Morbidity was only found to affect hot carcass weight and only second and third treatments at that. The second treatment decreased HCW by about 25 pounds while the third treatment diminished HCW by about 50 pounds. Nearly all studies that have examined the effect morbidity has on carcass quality found that morbidity negatively affects most or all carcass traits (Gardner et al., 1999; Stovall et al., 2000; Speer, Young, and Roeber, 2001; Schneider et al., 2009).

Some operators purchase feeder calves and retain ownership through slaughter. The purchase prices and price discounts to breakeven would be different over this much longer time period. Therefore these prices and discounts were calculated over this extended timeframe. The breakeven purchase price for the typical steer calf ranges from $94.13/cwt to $114.90/cwt, with discounts for morbidity ranging from $4.67/cwt to $20.77/cwt (Table 6.6). The breakeven purchase price for the typical arriving bull calf ranges from $88.29/cwt to $108.28/cwt, with discounts for castration and morbidity ranging from $6.63/cwt to $26.61/cwt (Table 6.6). Again, while useful, an average purchase price and discount to breakeven are more beneficial than the wide ranges. The morbidity probabilities were again applied to achieve these averages. The breakeven purchase price of a steer that will remain healthy is $114.90/cwt. Anticipating BRD morbidity, the average steer needs to be discounted $0.62/cwt for a purchase price of $114.28/cwt. For a bull, the average purchase price is $107.51/cwt, and the price discount relative to a "healthy" steer is $7.39/cwt. This results in an average price discount of $6.77/cwt for bulls relative to steers when taking into account the probabilities of both bulls and steers needing treatment for BRD.

The other component of this research examines the efficacies of three metaphylaxis drugs: Draxxin, Micotil, and Excede. In terms of performance, all explanatory variables were statistically significant. Most importantly, Excede was found to give cattle a performance advantage over both Draxxin and Micotil throughout the entire receiving trial; however, both Draxxin- and Micotil-administered cattle exhibited performance advantages over Excede-administered cattle in the time period from arrival to revaccination. Draxxin-treated calves were always found to have gain advantages over Micotil-treated calves. Presumably, the advantage of Excede is due to it keeping cattle healthier and, thus, on feed and gaining relative to those treated with Draxxin or Micotil and that this same advantage exists for Draxxin relative to Micotil. The morbidity logit models confirmed only half of this. Cattle treated with Draxxin were about 15% less likely to ever need treatment for BRD compared to those treated with Micotil; however, steers and bulls treated with Excede were 9% and 12%, respectively, more likely to ever need treatment for BRD compared to steers and bulls treated with Draxxin. The most likely explanation for Excede having a performance advantage over Draxxin yet having a morbidity disadvantage is that calves treated with Excede are treated earlier in the trial than calves treated with Draxxin, thus enabling them to exhibit greater compensatory gains.

Do the increased feeder calf performance and decreased chances of morbidity of Excede and Draxxin over Micotil compensate for their extra initial dosage costs? Breakeven purchase prices and discounts to breakeven and their averages were calculated for Draxxin-, Micotil- and Excede-administered cattle. For steers, the average breakeven purchase price if one was going to use Draxxin as the metaphylaxis drug is $113.57/cwt, and the Micotil and Excede complements are $112.71/cwt and $116.31/cwt, respectively. Therefore, if one was going to use Draxxin for metaphylaxis treatment, steers would need to be discounted $2.74/cwt more than if Excede was going to be used, and if one was going to use Micotil for metaphylaxis treatment, steers would need to be discounted $3.60/cwt. For bulls, the average breakeven purchase price when using Draxxin is $109.18/cwt, when using Micotil, it is $109.44/cwt and when using Excede, it is $110.40/cwt. Bulls would need to be discounted $1.22/cwt and $0.96/cwt more in order to breakeven if Draxxin or Micotil, respectively, was going to be used instead of Excede.

When comparing steers to bulls within treatments, the average breakeven purchase prices for steers are $113.57/cwt and $109.18/cwt for bulls administered Draxxin for an average discount to breakeven of $4.39/cwt for bulls. For calves administered Micotil, the average breakeven purchase price for steers is $112.71/cwt and $109.44/cwt for bulls, with an average price discount of $3.27/cwt for bulls. For calves administered Excede, the average breakeven purchase price for steers is $116.31/cwt and $110.40/cwt for bulls, with an average price discount of $5.91/cwt for bulls. The discounts for bulls are both higher and lower when examining metaphylaxis treatments than when examining just the effects of castration timing. These differences are a result of the disparity in performance between steers and bulls within each metaphylaxis treatment group.

The results of this research show the increased performance and diminished morbidity advantages of steer feeder calves compared to bulls. The obvious implication, as earlier demonstrated, is that buyers of stocker calves should discount bulls appropriately in order to breakeven or make a profit, and some male feeder calves, 65% of those in this study, are bulls. The other side of this equation is the cow/calf producer and what incentives or disincentives are there to sell steers and bulls. Bulls typically are and should be discounted; therefore cow/calf producers should be receiving less dollars per hundredweight than the comparable steer. However it has been shown by Marlowe and Gaines (1958) and others that bulls gain better than steers, approximately 5% faster, through weaning and thus would weigh more at the sale barn, so a producer may be able to make more money selling a heavier, discounted bull than a lighter, non-discounted steer.

It seems like the next obvious question would be “Is there a way for steers to maintain a gain comparable to that of bulls?” The answer is growth implants, and while the results are mixed, most studies indicate that at weaning, intact bulls have no body weight advantage over implanted steers (Lents et al., 2006). Gadberry analyzes growth implants for suckling and growing beef cattle and states that implants complement good management but do not compensate for poor management because of limited responses under poor management conditions. Suckling calves are expected to increase gain between 4 and 8%. Others (Ralston, 1978; Prichard et al., 1989; Woods et al., 1990) also found that implanted suckling calves had improved ADG and/or higher weaning weights than non-implanted suckling calves. However, Simms et al. (1988) and Bagley et al. (1989) did not find that growth implants significantly increased ADG or weaning weights for suckling calves.

There is also the issue of public and consumer acceptance of late-castrated cattle. Most animal welfare and animal rights organizations believe that if cattle are to be castrated, then castration should occur at young ages, as close to birth as possible, to minimize the pain and stress associated with castration. Currently castration is not a hotly-debated topic like livestock confinement is, but if general public opinion sways rules and regulations regarding castration, then the implications of the results of this study change. Price discounts to breakeven for bulls would be irrelevant as only steers would be sold at feeder calf auctions, or the price discounts to breakeven would be even greater that what was found in this study because if late-castration remained an option a local anesthetic would then be required, and castration might also be required to be done by a veterinarian, thus greatly increasing the costs to castration. Anesthesia and pain medication are required for castration in several European countries. Ireland requires anesthesia when castrating bulls older than six months, and regulations in England state that all bulls older than two months be given local anesthesia for castration and require that surgery is performed by a veterinarian (Larson, 2009). However, the decreased performance and increased susceptibility to BRD for bulls relative to steers reinforces that early castration has considerable economic benefits as demonstrated by the need to discount bulls at purchase.

The greatest issue concerning this research and ensuing results is that the backgrounding data available are from an unrealistic timeframe. The average receiving trial lasted just 44 days where true backgrounding operations typically feed cattle for a minimum of 90-120 days. The results from this research could be extrapolated to cover the extended timeframe, however great care and caution would need to be taken when making assumptions and interpreting the results.

Second, based on previous research, it seems that castration timing and particularly morbidity should have a greater effect on carcass traits and carcass quality. More carcass observations might assist in bringing more effects to light. Also, it would be very beneficial to have performance and morbidity data on the cattle for the intervening time at the feedlot, as 300 plus days on feed would likely have as great or greater effect on carcass quality as the average 44 days of known information.

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Appendix A - Other Carcass Characteristic Model Results

Table A.1 *REA* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	13.978	0.952	14.68	<.0001
Sex	-0.163	0.171	-0.95	0.3405
StartWt	0.000	0.002	-0.15	0.8828
Arrival Season (Default = Season0)				
Season1	-0.457	0.164	-2.78	0.0057
Source (Default = Source0)				
Source3	-0.020	0.170	-0.12	0.9053
Morbidity (Default = Morbidity0)				
Morbidity1	0.084	0.212	0.40	0.6922
Morbidity2	-0.892	0.274	-3.26	0.0012
Morbidity3	-0.250	0.530	-0.47	0.6372

Number of Observations = 376
RMSE = 1.534
Adj. R^2 = 0.0501

Table A.2 *BF* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	0.444	0.093	4.77	<.0001
Sex	-0.012	0.017	-0.70	0.4858
StartWt	0.000	0.000	0.07	0.9473
Arrival Season (Default = Season0)				
Season1	0.002	0.016	0.13	0.8953
Source (Default = Source0)				
Source3	-0.027	0.017	-1.61	0.1085
Morbidity (Default = Morbidity0)				
Morbidity1	-0.015	0.021	-0.72	0.4745
Morbidity2	0.032	0.027	1.21	0.2252
Morbidity3	-0.019	0.052	-0.37	0.7112

Number of Observations = 376
RMSE = 0.150
Adj. R^2 = -0.0044

Table A.3 Ordered Logit Estimates for *YieldGrade*

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	0.714	1.194	0.60	0.5498
Limit 2†	2.597	0.214	12.16	<.0001
Limit 3†	5.259	0.280	18.76	<.0001
Sex	-0.189	0.214	-0.89	0.3759
StartWt	0.005	0.003	1.92	0.0554
Season0		Default		
Season1	0.072	0.203	0.36	0.7214
Source0		Default		
Source3	-0.200	0.210	-0.95	0.3406
Morbidity0		Default		
Morbidity1	-0.170	0.266	-0.64	0.5222
Morbidity2	0.458	0.339	1.35	0.1772
Morbidity3	-0.829	0.657	-1.26	0.2072

Number of Observations = 377

Log Likelihood = -408.146

†The *Intercept* and *Limit* variables reported in "proc qlim" of SAS combine to form the category threshold values.

Table A.4 *MarblingScore* Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	311.859	52.761	5.91	<.0001
Sex	2.760	9.447	0.29	0.7703
StartWt	0.104	0.116	0.89	0.3736
Arrival Season (Default = Season0)				
Season1	6.738	9.104	0.74	0.4597
Source (Default = Source0)				
Source3	-6.893	9.398	-0.73	0.4638
Morbidity (Default = Morbidity0)				
Morbidity1	-4.914	11.733	-0.42	0.6756
Morbidity2	29.075	15.155	1.92	0.0558
Morbidity3	-14.121	29.355	-0.48	0.6308

Number of Observations = 376
RMSE = 84.966
Adj. R^2 = -0.0010

Table A.5 Binary Logit Estimates for *ChoicePlus*

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	1.399	1.432	0.98	0.3286
Sex	0.228	0.253	0.90	0.3676
StartWt	-0.001	0.003	-0.32	0.7478
Season0		Default		
Season1	0.081	0.249	0.33	0.7446
Source0		Default		
Source3	-0.253	0.253	-1.00	0.3191
Morbidity0		Default		
Morbidity1	-0.058	0.313	-0.19	0.8527
Morbidity2	0.870	0.513	1.70	0.0898
Morbidity3	-1.272	0.705	-1.80	0.0712

Number of Observations = 377
Log Likelihood = -209.150

Table A.6 Ordered Logit Estimates for *QualityGrade*

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	4.446	1.482	3.00	0.0027
Limit 2†	3.502	0.497	7.04	<.0001
Limit 3†	9.305	0.722	12.89	<.0001
Sex	0.305	0.249	1.23	0.2191
StartWt	0.000	0.003	-0.08	0.9337
Season0		Default		
Season1	0.114	0.244	0.47	0.6411
Source0		Default		
Source3	-0.158	0.250	-0.63	0.5284
Morbidity0		Default		
Morbidity1	-0.067	0.306	-0.22	0.8264
Morbidity2	1.310	0.550	2.38	0.0173
Morbidity3	-1.214	0.678	-1.79	0.0736

Number of Observations = 377
Log Likelihood = -244.670
†The *Intercept* and *Limit* variables reported in "proc qlim" of SAS combine to form the category threshold values.

Table A.7 Binary Logit Estimates for *CAB*

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	-1.488	1.553	-0.96	0.3380
Sex	0.046	0.280	0.16	0.8706
StartWt	0.000	0.003	0.13	0.9001
Season0		Default		
Season1	0.026	0.267	0.10	0.9215
Source0		Default		
Source3	-0.517	0.296	-1.75	0.0807
Morbidity0		Default		
Morbidity1	0.166	0.335	0.49	0.6208
Morbidity2	-0.005	0.461	-0.01	0.9905
Morbidity3	-0.576	1.088	-0.53	0.5961

Number of Observations = 377
Log Likelihood = -186.050

Table A.8 Binary Logit Estimates for *NAB*

Variable	Parameter Estimate	Standard Error	t Value	P value
Intercept	-4.031	2.111	-1.91	0.0562
Sex	0.538	0.403	1.33	0.1822
StartWt	0.004	0.005	0.82	0.4099
Season0		Default		
Season1	0.035	0.352	0.10	0.9216
Source0		Default		
Source3	-0.772	0.421	-1.83	0.0666
Morbidity0†		Default		
Morbidity1†	-0.211	0.478	-0.44	0.6597
Morbidity2†	0.110	0.586	0.19	0.8511

Number of Observations = 377
Log Likelihood = -120.086
†There were no NAB qualifying carcasses that had *Morbidity3*.