VALUE DETERMINANTS, ALTERNATIVE GRID PRICING STRUCTURES, AND SORTING IN A VALUE BASED CATTLE MARKETING SYSTEM

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Chapter I

Introduction

Domestic demand for beef declined sharply during the last several decades, which resulted in a loss of market share to the pork and poultry industries. Research indicates that health concerns, changing lifestyles, higher retail beef prices, and inconsistent quality are at the root of this decline in demand. Literature suggests that cash pricing of fed cattle has contributed to beef's inability to compete with other meats because it fails to transmit consumer preferences back through the system to the cattle producer. In the cash marketing system, the value of an animal is based on its live or dressed weight and an average price. The disadvantage of the cash marketing system is the likelihood that pens will include above-average cattle that are sold for less then market value and below-average cattle that are priced above market value. The price discovery process in the cash marketing system fails because incorrect or distorted information about individual animal value is passed back through the system. Value based marketing, primarily in the form of grid pricing, was introduced to replace the flawed cash marketing system. Grid pricing uses premiums and discounts based on USDA Yield and Quality Grades to calculate individual carcass prices. This discovered price is intended to provide producers with an incentive to raise and feed leaner cattle that still grade USDA Choice or Prime. Leaner cattle would eliminate revenue losses due to fat, which amount to about $2 billion per year, and provide consumers with the product they desire.

This thesis examines three important issues related to the value based marketing system that has been adopted by the beef industry:

- As price is determined on an individual carcass basis, animal values generated in a grid pricing system are expected to be more volatile than liveweight or dressed weight revenues. To avoid revenue losses, the price components that cause to the variability need to be identified and quantified
- All major packers and alliances offer feeders the opportunity to sell their cattle on the grid. The premiums and discounts offered in a specific grid will depend on the type of carcass that is desired by a particular packer or alliance. To ensure that profits are maximized, feeders must understand

the effects of alternative grid structures on cattle management decisions; more specifically, feeders must understand the effects of alternative grids on the number of days animals are fed.

- There is a potential for inefficiency and profit losses in the cattle feeding sector if production practices do not account and adjust for the heterogeneity of cattle. Ultimately, in a grid pricing system, feeders need sell each animal at its optimal endpoint to maximize profits and feeding efficiencies. Therefore, the returns to sorting animals into homogeneous groups prior to marketing need to be measured.

Each of these issues is addressed in three independent chapters. The following is brief introduction of each chapter found in this thesis.

Effects of Specific Carcass Characteristics on the Volatility of Animal Value

The first article, "The Impact of Grid Pricing Premiums and Discounts on Individual Animal Values", uses Southern Plains feedlot data, a two-stage process using Coefficients of Separate Determination, and sensitivity analysis to quantify the effects of specific carcass characteristics on the volatility of animal value and the price signals sent back to producers and feeders about product quality.

This research improves upon and adds to the current literature in several ways. First, it employs a two-stage process that uses Coefficient of Separate Determination to (A) quantify the effects of grid price and hot carcass weight on animal value and (B) measure the influence of quality and yield grades on grid price. Second, sensitivity analysis is used to determine how changes in grid premiums and discounts affect the information sent back to producers about desirable carcass characteristics.

Effects of Alternative Grid Structures

The second article, "Impact of Alternative Grid Pricing Structures on Cattle Marketing Decisions", studies the interaction between the number of days cattle are feed and their quality grade, yield grade, and other feedlot performance factors that explain much of the variation in profit under grid pricing. The main objective of this paper is to increase the profitability of cattle feeding operations by determining how the optimal number of days on feed changes under different grid pricing structures. To achieve this objective, this research uses growth models, logistic regression, and an optimization process.
The unique nature of this research is that it uses profit to determine the optimal endpoint of feeding cattle. Previous research on fed cattle pricing has considered only the revenue impacts of alternative pricing

systems (Feuz, Fausti, and Wagner; Feuz; Schroeder and Graff). However, as revenue only considers price and not costs, high selling prices do not necessarily equate to high profits. As the best economic indicator of the appropriate endpoint is profit, this study will augment past studies on grid pricing by considering the cost changes associated with obtaining different quality and yield grade levels.

Returns to Sorting in a Grid Pricing System

The third article, "Effects of Sorting and Heterogeneity on Cattle Marketing Decisions ", determines whether sorting animals prior to marketing will result in more profitable cattle feeding operations and more desirable carcass characteristics. The main objective of this research is to determine the value of sorting and identify the effect of sorting on days on feed and carcass quality for cattle being sold in a grid pricing system. To achieve this objective, this research uses growth models, logistic regression, an optimization process, and three sorting systems.

Very little research has been done in the area of sorting and its effects on cattle feeding profits and marketing decisions. Much of the research that has been done looked at the economic benefits of adopting an ultrasound sorting system (Koontz et. al.; Brethour; Houghton and Turlington). This research improves and expands previous research in two ways. First, it uses a simple sorting technique based on placement weight that is currently used by cattle feeders. Second, it identifies how marketing decisions change when a pen of cattle becomes more heterogeneous.

Structure of Chapters

Chapters II through IV present each of the above articles in their entirety. Each chapter is written in the style of a journal article. The tables, charts, and figures referenced in the text of each chapter will appear at the end of that chapter. The references cited in each chapter will appear in a reference list at the end of the thesis. Chapter V summarizes the findings, conclusions and limitations of each article. Additional information and detail relating to the articles in Chapters II through IV can be found in the appendices at the end of the thesis.

Chapter II

The Impact of Grid Pricing Premiums and Discounts on Individual Animal Values

Abstract

The number of fed cattle sold on an individual carcass basis has increased steadily from 1980. Southern Plains feedlot data, a two-stage process using coefficients of separate determination, and a sensitivity analysis are used to quantify the effects of specific carcass characteristics on the volatility of animal value and the price signals sent back to producers and feeders about product quality in a value based marketing system. This research found that certain grids cause carcass weight to explain up to 66% of the variability in value. The remaining variability is explained by quality grade (10%), yield grade (14%) and light/heavy weight discounts (10%). As $135 of the estimated grid value differences can be apportioned to liveweight, the remaining $57 of the grid value difference can be attributed to quality differences.

Key Words: efficiency, fed cattle, grid pricing, price discovery, value based marketing

Introduction

In recent years, value based marketing has become prevalent. Between 1980 and 1994, the number of cattle marketed in a value based marketing system increased 17%. In 1995, more than 46% of all cattle were marketed in a value based marketing system (Grain Inspection, Packers and Stockyards Administration). Value based marketing appears to have become more accepted for two reasons. First, research by Feuz, Fausti, and Wagner indicates that on average carcass prices generate higher animal values than live weight prices. The reason for this is generally attributed to packers being willing to pay more for carcasses because (A) the risk of inaccurately estimating carcass characteristics is eliminated and (B) typically higher quality cattle are sold in the value based marketing system. Second, prices are determined on an individual animal basis using actual carcass characteristics. As a result, prices discovered within this system are better estimates of the wholesale final product value of the carcass (Feuz). In other words, with more information regarding product quality, the price signals sent back through the marketing channel are stronger and more accurate (Feuz, Fausti, and Wagner). Therefore, prices and the associated price signals generated under a value based system should encourage industry-wide changes, which can result in a more efficient and responsive industry. This study will focus upon the price signals that grid pricing, which is a type of value based pricing, conveys back through the marketing system.

Grid pricing avoids the average pricing of animals and carcasses by applying discounts and premiums to a base price. The discounts and premiums applied will depend on an individual carcass' quality grade, yield grade, and dressed weight. Since the grid pricing system communicates the value differences among carcasses, producers have specific carcass merit and value data on each carcass they sell. Those who support grid pricing believe that this information will create incentives for producers to improve beef animal and product quality by identifying and rewarding the production of superior quality beef. The purpose of this paper is to determine what carcass characteristics cause variation in individual animal values given current grid pricing premiums and discounts.

Previous Research

A very limited amount of research has been done on value based marketing. Most of the existing research in this area has compared the efficiency and risk associated with liveweight, dressed weight, and value based pricing. Feuz, Fausti, and Wagner found that carcass quality information has the greatest impact on profits because of the improvement in the accuracy and efficiency of price signals. Also, the authors determined that liveweight, dressed weight, and grid pricing methods convey different signals back through the marketing system. Grid pricing was found to send the strongest signal regarding desirable carcass characteristics.

Feuz uses regression to examine the variability of revenue of fed cattle under liveweight, dressed weight, and grid pricing methods. Individual animal revenue variability was the greatest under a grid pricing system and lowest under a liveweight pricing system. His use of coefficients of separate determination found that weight accounts for 38 to 78 percent of the variation in individual animal value in a grid pricing system. However, the author assumes that the relationship between yield grade and value is linear and the yield grade variable is continuous.

This research improves upon and adds to the current literature in several ways. First, it employs a two-stage process that uses coefficients of separate determination to (A) quantify the effects of grid price and hot carcass weight on animal value and (B) measure the influence of quality and yield grades on grid price. Second, sensitivity analysis is used to determine how changes in grid premiums and discounts affect the information sent back to producers about desirable carcass characteristics.

Grid Pricing

The term grid refers to a matrix of premiums and discounts. The rows of the matrix consist of the USDA quality grades and the columns consist of the USDA yield grades. Quality grades for steers or heifers are Prime, Choice, Select, and Standard. Quality grades, which are indicative of the eating quality of the meat, are assigned based on amount of marbling in the ribeye and the age of the animal. Prime carcasses have more marbling so they receive premiums. As the degree of marbling in Select and Standard carcasses is less, these carcasses get discounted. Yield Grades 1 through 5 are the expected percent of boneless, closely trimmed retail cuts from the round, loin, rib, and chuck on a carcass weight basis. Yield grades are formula determined based on four factors: carcass weight, thickness of fat over the ribeye, area of the ribeye muscle, and percentage of kidney, pelvic, and heart fat. Carcasses with a Yield Grade 1 or 2 have the highest percentage of lean cuts and the least amount of fat so they receive premiums. Having more fat and lower cutability, Yield Grades 4 and 5 earn discounts. Most grids use the value of a Choice, Yield Grade 3 carcass weighing 550-950 pounds as the base price. There are several base prices that are typically used: weekly plant average prices, highest reported price in a specific geographic region, boxed beef cutout value, futures market price, or a negotiated price.

In October of 1996, the USDA-AMS began publishing weekly averages of premiums and discounts found in the grids of the seven, now six, largest packers. Table 2.1 is a sample "additive grid" based on the averages appearing in *National Carcass Premiums and Discounts for Slaughter Steers and Heifers* during the week of December 28, 1998. The grid is said to be "additive" because it is derived by adding together the quality grade and yield grade discounts/premiums reported by the USDA. For example, the grid premium for a Prime, Yield Grade 1 animal is not reported by the USDA but is derived by adding the premium for Prime (+5.67) together with the premium for Yield Grade 1 (+1.67) to obtain +7.34.

Carcass and Price Data Description

This study used the carcass characteristics of 1,278 head of fed cattle in 18 pens slaughtered by a major Southern Plains feedlot. On average, there were 71 animals per pen. The carcass characteristics of all 1,278 head are summarized in Table 2.2 and Table 2.3.

The cattle in this analysis had an average liveweight of 1,200 pounds. With an average hot carcass weight of 779 pounds, the average dressing percentage is 65 percent. Over 51 percent of these cattle had Choice or Prime quality grades and 11.4 percent achieved a Yield Grade of 4 or 5. Given that the National Beef Cattleman's Association and meatpackers are aiming for 70% Choice/Prime, 30% Select and 0% Standard (National Beef Quality Audit), these carcasses would be considered below targeted quality grade standards. However, in 1993, Cattleman's Carcass Data Service reported that 48.9 percent of the cattle in the industry grade Choice or Prime and 8.4 percent are Yield Grade 4 or 5. When compared to industry carcass data, the animals in this study are above average in quality grade and slightly below average in yield grade.

Prices used to calculate live, dressed and grid values appear in Table 2.4. The live and dressed prices are the weekly weighted average prices in Dodge City, Kansas during the week ending on December 31, 1998. Live value was calculated by multiplying liveweight and live price. Dressed value is the product of hot carcass weight and dressed price. The base grid price used in this analysis is the boxed beef cutout value for Choice carcasses between 550 and 850 pounds for the week ending December 26, 1998.

The grid used in this study is presented in Table 2.5. It is based on grid information published in the *National Carcass Premiums and Discounts for Slaughter Steers and Heifers* between October 1996 and December 1998. The premiums and discounts used reflect typical or average premiums and discounts in place during the analysis. The grid used in this analysis may differ from grids used by individual packers. For example, some grids apply only the smallest discount and other grids only apply quality and yield premiums to carcasses within a narrow weight range. In addition, there are grids that pay the same price for Standard carcasses regardless of yield grade. Often, these grids require a certain percentage of Choice carcasses before any premiums are applied. As the grid in this analysis uses industry aggregated data and applies all applicable quality, yield and weight premiums and discounts to every animal, it may be an extreme version of actual grids. Therefore, the results should give a clear indication of what components drive the grid value of an animal.

Procedures

A critical part of this analysis is to determine the percent variation in individual animal values in a grid pricing system that is due to differences in weight and quality. Previous studies have specified individual animal values under a grid pricing system as follows:

(1) $$GridValue = f(HCW, QG1, QG3, QG4, YG1, YG2, YG4, YG5, LH)$$

where:

HCW is hot carcass weight.
QG1 is equal to 1 if an animal graded Prime and 0 otherwise.
QG3 is equal to 1 if an animal graded Select and 0 otherwise.
QG4 is equal to 1 if an animal graded Standard and 0 otherwise.
YG1 is equal to 1 if an animal received a Yield Grade 1 and 0 otherwise.
YG2 is equal to 1 if an animal received a Yield Grade 2 and 0 otherwise.
YG4 is equal to 1 if an animal received a Yield Grade 4 and 0 otherwise.
YG5 is equal to 1 if an animal received a Yield Grade 5 and 0 otherwise.
LH is equal to 1 if an animal received a light (< 550 pounds) or heavy (>950 pounds) weight discount and 0 otherwise.

This model uses Choice, Yield Grade 3 as a base.

Previously, the relationship in Equation 1 was estimated using OLS results together with coefficients of separate determination to find the percentage of variation in grid value due to each independent variable. Coefficients of separate determination (CSD) allocate the explained variation in a regression model among the independent variables. Each CSD value represents the amount of variation in the dependent variable explained by a specific independent variable. The sum of the coefficients of separate determination for a specific model equals the coefficient of multiple determination, R^2. One minus R^2 is the variation in value that is not explained by the variables in the model. In an n variable model, coefficients of separate determination are equal to:

(2)
$$CSD_1 = \sum_{i=1}^{n} \beta_1 \beta_i r_{1i}$$
$$\vdots$$
$$CSD_n = \sum_{i=1}^{n} \beta_n \beta_i r_{ni}$$

where β is a standardized regression coefficient and r is the Pearson correlation coefficient. The calculation of the standardized regression coefficient is:

(3)
$$\beta_n = b_n * \left(\frac{s_n}{s_y} \right)$$

where b_n is the OLS regression coefficient for quality variable n, s_n is the standard deviation for quality variable n, and s_y is the standard deviation for the dependent grid value variable (Ezekiel and Fox).

The CSD methodology requires the relationship between the independent variables and the dependent variable whose variation is being explained to be linear and additive. Therefore, in previous research, the CSD approach was inappropriate because the relationship in Equation 1 is not a linear or additive. HCW has a multiplicative relationship with the other variables in the equation (i.e. all the variables jointly determine value), so Equation 1 has an R^2 of 1.

To solve this problem, this research uses a two-stage approach to determine the effect of carcass characteristics on animal value. In the first stage, the model is a double log function that describes the relationship between grid price, hot carcass weight (HCW), and grid value.

(4) Log(*Grid Value)* = g[Log(*Grid Price*), Log(*HCW*)]

As this relationship is specified in logs, it is additive and a linear identity. Thus, there is no need to estimate the parameters using OLS regression because each parameter will be equal to 1.

In the second stage, the model uses dummy variables to describe the relationship between grid price and quality grade, yield grade and carcass weight discounts. This model is specified such that Choice is the base quality grade, Yield Grade 3 is the base yield grade, and 550 to 950 pounds is the base carcass weight. That is,

$$\text{(5)} \qquad \textit{Grid Price} = \text{h}(QG1, QG3, QG4, YG1, YG2, YG4, YG5, LH)$$

where the variables in this equation are the same as those defined in Equation 1. As this linear and additive model is also an identity, it does not need to be estimated with OLS because the coefficient associated with each dummy variable is equal to its respective premium or discount.

The coefficients of separate determination were calculated in both stages. The CSD values for the variables in Equation 4 determine the amount of variation in total animal value due to weight and price variation. Variation in grid price is then broken down among the variables in Equation 5. To determine the effect of each variable in Equation 5 on animal value instead of price, the CSD value associated with each variable in Equation 5 is multiplied by the CSD value associated with price in Equation 4. This two-stage process quantifies the effects of weight, quality grades, and yield grades on animal value under grid pricing.

As the coefficients of separate determination indicate which carcass components are being rewarded under the different grids, sensitivity analysis can be used to determine how changes in the most volatile premiums and discounts affect the relationship between carcass characteristics and animal value. The effects of different premiums and discounts may indicate what changes have the greatest impact on price signals. Additionally, the top 25% of the cattle based on grid value are compared to the bottom 25% to identify any differences in the relationship between carcass characteristics and grid value and to quantify the value of the carcass characteristics.

Results

Base Grid

The results of the coefficients of separate determination calculations are presented in Figure 2.1. Most of the variation in value, 66 percent, is explained by carcass weight. The remaining 34 percent of the total variation is explained by price. The sources of variation in price are divided as follows: Yield Grade 14%, Quality Grade 10%, and light and heavy carcass discounts 10%. The standard deviation of animal values under grid pricing was found to be $82.77. Given that price variation due to carcass characteristics explained 34 percent of the total variation, $28.14 of this $82.77 standard deviation can be attributed to carcass quality characteristics.

Alternative Grids

Three different sensitivity analyses were performed to determine how changes in the grid affect the explanatory power of the carcass characteristic variables. Historical data indicate that certain premiums and discounts in the grid are quite volatile while others remain stable. Between October 1996 and December 1998, the most volatile price spreads are the Choice-Select and Choice-Standard spreads. The Choice-Prime spread is very stable. As shown in Figure 2.2, the spread between Choice and Select varied between -$2 and -$19.30. During this same period, the spread between Choice and Standard ranged between -$12.70 and -$27.45. The average Choice-Prime spread was approximately $5.60.

Much of the volatility in yield grade premiums and discounts occurs in Yield Grades 4 and 5. As detailed in Figure 2.3, premiums for Yield Grades 1, 2 and 3 are relatively stable. Yield Grade 4 discounts ranged from -$11.30 to -$16.30 and Yield Grade 5 discounts varied between -$16.70 and -$21.30.

The first analysis determined the effects of changes in the Choice/Select spread by increasing and decreasing the spread one and two standard deviations, ceteris paribus. As movements in the Standard discount mirror changes in the Select discount, changes in the Choice/Select spread are accompanied by similar changes in the Choice/Standard spread. Standard deviations of -$3.67 and -$2.69 were used for the Choice/Select spread and the Choice/Standard spread, respectively. The results appear in Table 2.6. Wider (Narrower) Choice/Select spreads result in larger (smaller) premiums and discounts on quality. As the spread widens (narrows), weight explains less (more) of the variability in value and the amount explained by quality grade increases (decreases). In all cases, the variability in value explained by yield grade and weight discounts changes very little.

The second analysis identifies the changes in explanatory power when the Yield Grade 3/4 and 3/5 spreads are changed one and two standard deviations, all else constant. Deviations of -$1.71 and -$1.63 were used for Yield Grade 3/4 and 3/5, respectively. The results presented in Table 2.7 indicate none of the carcass characteristics experienced a significant change in explanatory power when yield grade spreads change.

The last analysis, which appears in Table 2.8, simultaneously widens the Choice/Select spread and Yield Grade 3/4 spread by one and two standard deviations, while increasing the base price. In both cases, the explanatory power of weight declined while quality grade explained more of the variability in value and the variability of value due to yield grade and weight discounts remained relatively constant.

Despite changes to the structure of the grid, the explanatory power of weight dominates the explanatory power of the other carcass characteristics. Weight explains from 50 to 75 percent of the variation in value. There were only two cases that substantially increased the explanatory power of a non-weight related carcass characteristic. Significant increases of quality premiums and discounts (2 standard deviation widening of the Choice/Select spread – analysis 1 and 3) caused the explanatory power of quality grade to increase from 10 percent to 30 percent (analysis 1) and 24 percent (analysis 3).

Good versus Poor Quality Cattle

Perhaps the most intuitive way to determine the rewards that grid pricing provides to superior quality cattle is to consider the value of quality characteristics that grid pricing would generate for the top quartile of cattle in the data set versus the bottom quartile. When the top 25 percent of cattle on a grid value basis are compared to the bottom 25 percent, some striking differences become apparent. Table 2.9 indicates that animals earning more under a grid pricing system typically grade Choice, Yield Grade 3 or better and have heavier live and dressed weights but are not classified as heavy carcasses. The coefficients of separate determination for these higher valued animals, which appear in Table 2.10, show that weight is a relatively more important factor in determining the value of individual animals in this top quartile than it is for the entire population. This is the case because these animals are very uniform in quality. Specifically, almost

71 percent of these cattle grade Choice, Yield Grade 3 or better. By contrast, in the bottom quartile of cattle, quality characteristics explain more of the variation in animal value than is the case for the total population. In fact, quality characteristics explain almost half of the variation in individual animal values. While animals in the bottom quartile are widely dispersed among quality and yield grades, 32.4 percent of these cattle receive large discounts for having a Standard quality grade or a yield grade of 4 or 5. In addition, the animals in the bottom quartile were, on average, nearly 230 pounds lighter.

One would expect that animals in the bottom quartile of grid value could earn more if they were sold on a liveweight basis and animals in the top quartile could earn more if they were sold on a grid system. Table 2.11 indicates this is the case; however, animals in both quartiles could earn the most if they were sold on a dressed basis. The difference in average value of an animal in the top quartile versus the bottom quartile under the grid pricing system is $207.38. On the surface this appears to be more than adequate incentive to produce quality cattle. However, it will be shown below that much of this difference is due to weight and not quality.

The differences in average live and dressed value between the top and bottom quartiles are totally due to weight; these difference can be used to quantify the value of weight and quality in a grid pricing system. This analysis found live and dressed value differences of $135.13 and $150.25, respectively. Based on these differences, it is inferred that $57 or $72 ($207.38 minus either $135.13 or $150.25) of the difference observed between the average grid value of an animal in the top versus and bottom quartile of cattle is due to quality differences. Additionally, the average estimated value difference due to weight ($142.69 – the average of $135.13 and $150.25) is 68.8% of the total difference in per animal value between the two quartiles under grid pricing ($207.38). This percentage compares very favorably to the 66 percent of variation explained by carcass weight in the base grid coefficient of separate determination analysis.

Summary

Grid pricing is intended to facilitate the transmission of economic signals from consumer to producer. Using USDA Quality and Yield Grades to determine the value of an animal will provide producers with more information about the quality of cattle that they are producing. With more information, producers have an improved potential to change their management practices to produce a better quality product.

This research found that 34 percent of the variation in animal value under grid pricing is the result of price premiums and discounts for quality characteristics. Specifically, quality grade, yield grade and light and heavy carcass discounts explain 10 percent, 14 percent, and 10 percent of the variability in total animal values. Weight, which accounts for all of the variation of live and dressed carcass weight pricing, accounts for the remaining 66% of the variation in the value of animals sold on a grid. Therefore, weight rather than quality characteristics still dominates cattle producer's decisions about how to produce cattle and when to sell them on the grid. However, it is important to note that for the base grid used in this research yield grade may be a slightly more important quality factor in explaining variation in animal value.

Grid pricing was used to value 1,278 head of cattle for which carcass data were available. If the cattle in this sample are divided into quartiles based on each animal's grid value, the difference in grid value between the average animals in the top quartile versus the bottom quartile is $207.38. As $135 (liveweight) to $150 (dressed weight) of the grid value difference can be apportioned to weight, the remaining $57 to $72 of the grid value difference between the two quartiles can be attributed to quality differences.

Implications

No estimates have been made here of how much it costs to change the quality of cattle in the lower quartile of cattle so they have carcass characteristics similar to cattle in the upper quartile, nor is an estimate of this type known to exist. Therefore, it is not clear whether $57 or $72 premiums from selling on the grid are large enough to provide incentives to adjust feedlot production practices and cow/calf genetic selection decisions. To determine whether these premiums are large enough to encourage cattle quality improvements, several things need to be considered. While these quality premiums are 3-5 times more than "average" cattle feeding profits, one has to determine whether increases in feeding costs will exceed this 10 percent gain in revenues. Additionally, one must establish if a potential gain of $135 to $150 from increasing the weight of cattle in the lower quartile can be achieved without adversely affecting quality.

Table 2. 1 Additive Grid Based on National Carcass Premiums and Discounts for Slaughter Steers and Heifers Average Premiums and Discounts During the Week of December 28, 1998 ($/cwt.)

Quality	Yield Grade 1	Yield Grade 2	Yield Grade 3	Yield Grade 4	Yield Grade 5
Prime	7.34	6.50	5.67	-9.33	-14.33
Choice	1.67	0.83	Base	-15.00	-20.00
Select	-4.61	-5.99	-6.28	-21.28	-26.28
Standard	-13.99	-14.83	-15.66	-30.66	-35.66

Table 2.2 Yield Grades, Quality Grades, and Light and Heavy Carcasses for the 1,278 Head of Fed Cattle Used in Coefficients of Separate Determination Analysis (%)

Quality	Yield Grade 1	Yield Grade 2	Yield Grade 3	Yield Grade 4	Yield Grade 5	Total
Prime	0.0	0.2	0.4	0.2	0.0	0.8
Choice	3.8	19.5	19.5	7.2	0.4	50.3
Select	7.4	21.6	13.0	3.1	0.4	45.5
Standard	1.8	0.9	0.4	0.1	0.0	3.2
Total	13.0	42.2	33.3	10.6	0.8	
Light Carcasses		0.6				
Heavy Carcasses		2.9				

Table 2.3 Liveweight and Hot Carcass Weight for the 1,278 Head of Fed Cattle Used in Coefficients of Separate Determination Analysis

Weight	Average	Std Dev
Live	1,200	136.6
Hot Carcass	779	86.6

Table 2.4 Cash, Dressed and Base Grid Prices Used to Calculate Animal Value

Live Price ($/pound)	$0.60
Dressed Price ($/pound)	$0.95
Base Grid Price ($/hundredweight)	$96.08

Table 2.5 Base Grid Used in Coefficients of Separate Determination Procedure Utilizing Published *National Carcass Premiums and Discounts for Slaughter Steers and Heifers* Average Premiums and Discounts between October 1996 and December 1998 ($/cwt)

Quality	Yield Grade 1	Yield Grade 2	Yield Grade 3	Yield Grade 4	Yield Grade 5
Prime	103.49	102.66	101.77	88.07	82.57
Choice	97.80	96.97	96.08	82.38	76.88
Select	90.88	90.05	89.16	75.46	69.96
Standard	80.75	79.92	79.03	65.33	59.83

Table 2.6 Coefficients of Separate Determination for Different Choice/Select and Choice/Standard Spreads

		Analysis 1 - Choice/Select and Choice/Standard Spreads			
	Base Grid	2 Std Dev Wider	1 Std Dev Wider	1 Std Dev Narrower	2 Std Dev Narrower
Part 1:					
Price	0.34	0.50	0.41	0.28	0.25
Carcass Weight	0.66	0.50	0.59	0.72	0.75
Total	1.00	1.00	1.00	1.00	1.00
Part 2:					
Quality	0.10	0.29	0.19	0.04	0.02
Yield	0.14	0.11	0.13	0.14	0.14
Light/Heavy	0.10	0.09	0.10	0.10	0.09
Total	0.34	0.50	0.41	0.28	0.25
Select Discount	$6.92	$13.86	$10.39	$3.45	$0.00
Mean of Grid Value	$704.64	$678.75	$691.70	$717.59	$730.47
Std Dev of Grid Value	$82.77	$92.87	$86.93	$80.68	$80.80

Table 2.7 Coefficients of Separate Determination for different Yield Grade 3/4 and 3/5 Spreads

	Base Grid	Analysis 2 - Yield Grade 3/4 and 3/5 Spreads			
		2 Std Dev Wider	1 Std Dev Wider	1 Std Dev Narrower	2 Std Dev Narrower
Part 1:					
Price	0.34	0.40	0.37	0.31	0.28
Carcass Weight	0.66	0.60	0.63	0.69	0.72
Total	1.00	1.00	1.00	1.00	1.00
Part 2:					
Quality	0.10	0.09	0.10	0.10	0.10
Yield	0.14	0.21	0.17	0.11	0.08
Light/Heavy	0.10	0.10	0.10	0.10	0.10
Total	0.34	0.40	0.37	0.31	0.28
Yield Grade 4 Discount	$13.70	$17.12	$15.41	$11.99	$10.28
Mean of Grid Value	$704.64	$701.37	$703.01	$706.28	$707.91
Std Dev of Grid Value	$82.77	$85.14	$83.84	$81.94	$81.37

Table 2.8 Coefficients of Separate Determination Given Global Changes

	Base Grid	Analysis 3 – Global Changes	
		Yield 3/4 & 3/5 – 1 Std Dev Wider Choice/Select & Choice/Standard – 1 Std Dev Wider base price + 5	Yield 3/4 & 3/5 – 2 Std Dev Wider Choice/Select & Choice/Standard – 2 Std Dev Wider base price + 10
Part 1:			
Price	0.34	0.40	0.47
Carcass Weight	0.66	0.60	0.53
Total	1.00	1.00	1.00
Part 2:			
Quality	0.10	0.17	0.24
Yield	0.14	0.14	0.15
Light/Heavy	0.10	0.09	0.08
Total	0.34	0.40	0.47
Mean of Grid Value	$704.64	$729.00	$753.35
Std Dev of Grid Value	$82.77	$90.74	$99.97

Table 2.9 Comparison of Carcass Characteristics for Cattle in the Top and Bottom Quartile of Grid Value

Top 25%

Percentage by Quality and Yield Grade

Quality	Yield Grade 1	Yield Grade 2	Yield Grade 3	Yield Grade 4	Yield Grade 5	Total
Prime	0.00	0.00	0.31	0.31	0.00	0.62
Choice	4.67	30.84	34.89	2.49	0.00	72.90
Select	3.43	11.53	11.53	0.00	0.00	26.48
Standard	0.00	0.00	0.00	0.00	0.00	0.00
Total	8.10	42.37	46.73	2.80	0.00	

Number of Carcasses	321
Average Liveweight	1310.6
Average Hot Carcass Weight	855.9
Percentage of Light Carcasses	0.00
Percentage of Heavy Carcasses	0.93

Bottom 25%

Percentage by Quality and Yield Grade

Quality	Yield Grade 1	Yield Grade 2	Yield Grade 3	Yield Grade 4	Yield Grade 5	Total
Prime	0.00	0.00	0.31	0.00	0.00	0.31
Choice	1.89	11.01	6.60	10.38	0.63	30.50
Select	11.01	29.56	7.23	9.43	1.57	58.81
Standard	5.97	3.46	0.63	0.31	0.00	10.38
Total	18.87	44.03	14.78	20.13	2.20	

Number of Carcasses	318
Average Liveweight	1085.0
Average Hot Carcass Weight	697.7
Percentage of Light Carcasses	2.52
Percentage of Heavy Carcasses	4.09

Table 2.10 Comparison of Coefficients of Separate Determination for Cattle in the Top and Bottom Quartile of Grid Value

Top 25%		Bottom 25%	
Coefficients of Separate Determination for Grid Value		Coefficients of Separate Determination for Grid Value	
Part 1:		Part 1:	
Price	0.24	Price	0.49
Carcass Weight	0.76	Carcass Weight	0.51
Total	1.00	Total	1.00
Part 2:		Part 2:	
Quality	0.08	Quality	0.09
Yield	0.10	Yield	0.23
Light/Heavy	0.06	Light/Heavy	0.17
Total	0.24	Total	0.49

Table 2.11 Comparison of Per Head Values for Cattle in the Top and Bottom Quartile of Grid Value

	Top 25%		Bottom 25%	
Value per Head	Average	Std Dev	Average	Std Dev
Live	$785.06	$56.37	$649.93	$80.96
Dressed	$812.71	$44.54	$662.46	$83.90
Grid	$805.32	$34.65	$597.94	$54.84

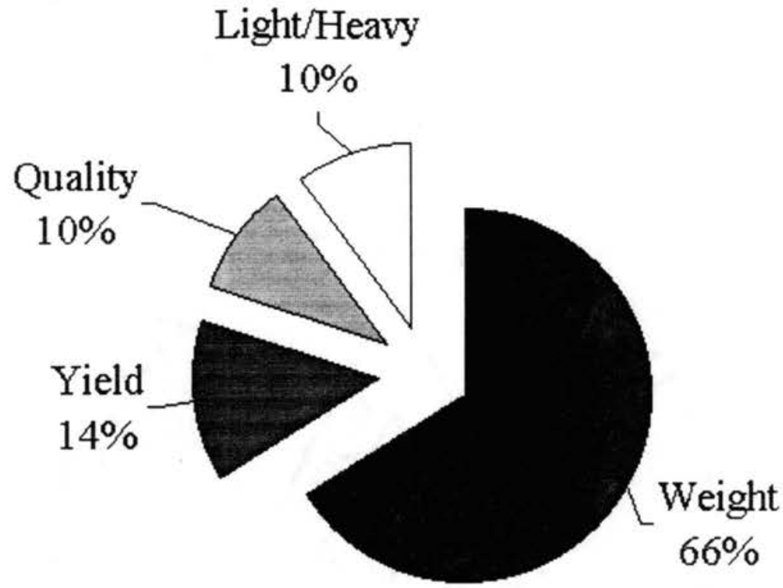

Figure 2.1 Percentage of Variation in Grid Value Explained by Carcass Characteristics

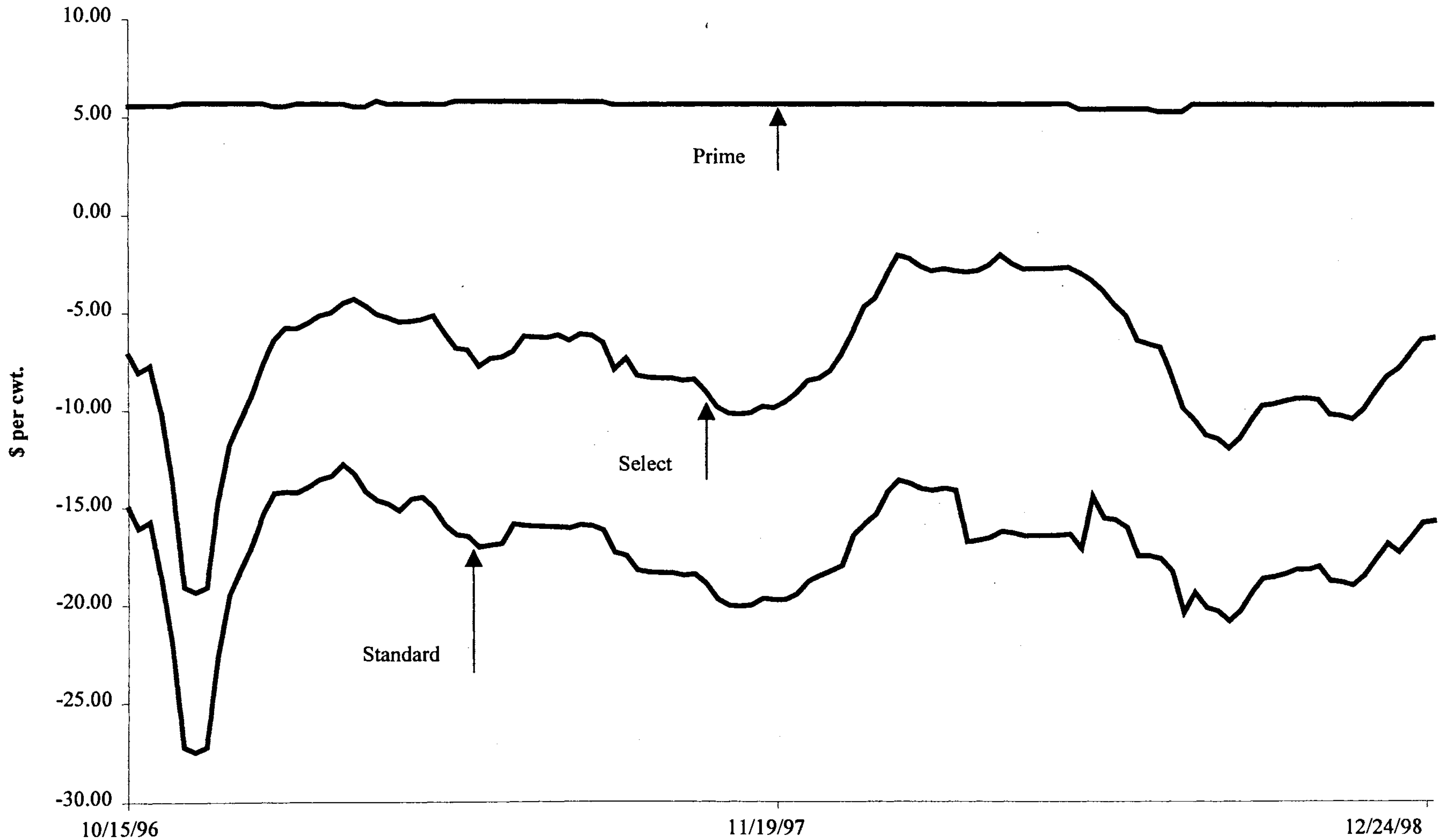

Figure 2.2 USDA Quality Grade Grid Average Premiums and Discounts from October 1996 to December 1998

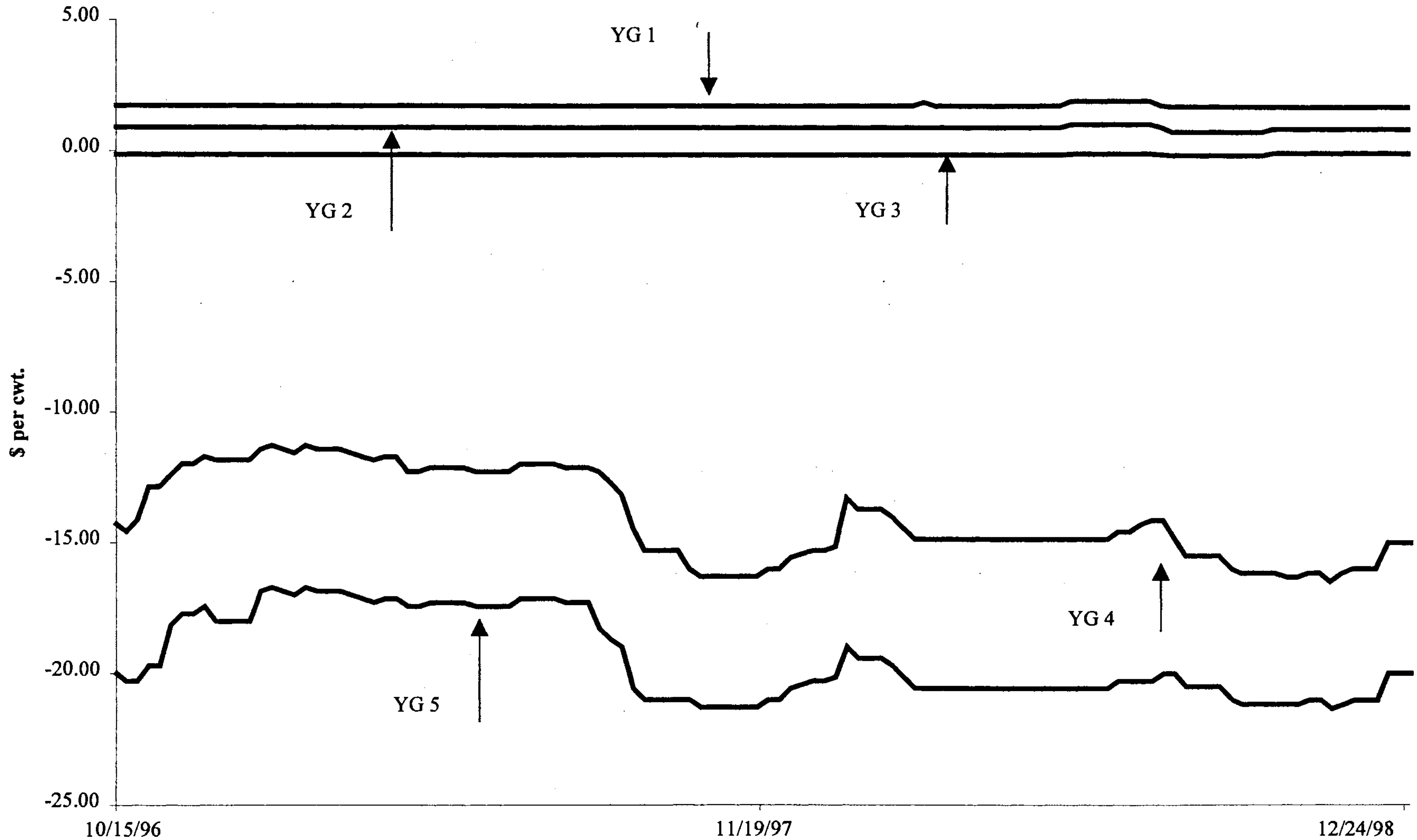

Figure 2.3 USDA Yield Grade Grid Average Premiums and Discounts from October 1996 to December 1998

Chapter III

Impact of Alternative Grid Pricing Structures on Optimal Fed Cattle Marketing Dates

Abstract

Quality grade, yield grade, and weight explain the variation in profit under grid pricing. Feedlot owners can change profits by adjusting time on feed to influence these performance factors. This research uses growth models, logistic regression, and an optimization process to determine how the optimal number of days on feed changes under different pricing structures. The important effects of the pricing structures on fed cattle marketing decisions are:

- The structure of the grid, primarily the relationship between quality grade discounts and yield grade discounts, affects the number of days on feed. More specifically, large quality grade discounts and small yield grade discounts increases the number of days on feed. While small quality grade discounts and large yield grade discounts result in fewer days on feed.
- A $1 increase in the Choice/Select spread, all else constant, will cause the number of days on feed to increase about 1.1 days.
- A $1 increase in the Yield Grade 3/4 spread, all else constant, will cause days on feed to decrease by 1.5 days.
- There is a negative relationship between the number of days on feed and feed price. For every $1 per ton increase in feed price, days on feed will decline .09 days, all else constant.

Keywords: grid pricing, profits, animal growth, logistic regression, days on feed.

Introduction

Between 1980 and 1995, the percentage of cattle marketed in a value based marketing system increased from 29% to more than 46% (Grain Inspection, Packers and Stockyards Administration). Fewer cattle are being sold on a pen basis for an average price. Rather, a price per hundredweight of carcass weight is computed for each individual animal and the price received is dependent on specific carcass characteristics. Therefore, decisions relating to the marketing of slaughter cattle have become more complex with the advent of value based marketing.

The carcass characteristics used to develop a value based price are carcass weight, quality grade, and yield grade. Marketing becomes more complex because the length of time a given pen of cattle is on feed affects weight, quality grade, and yield grade. Weight, both live and carcass, increases with days on feed. Thus, the probability of receiving a discount for a heavy carcass increases with days on feed. Length of time on feed will have a positive effect on quality grade. The longer an animal is on feed, the more likely it is to grade Choice or Prime and the more likely it is to acquire a premium. A negative relationship exists between yield grade and days on feed. An animal is more likely to achieve a Yield Grade 4 or 5 and a discount as days on feed increases. However, it is important to note that the larger premiums received from quality grade improvements may not offset the losses associated with the simultaneous decline in yield grade. Additionally, the longer cattle are on feed, the less efficient they become at converting feed into weight gains. Given the quality grade and yield grade trade-off and the steady increases in the cost of gain per pound, the optimal number of days on feed for cattle that will be sold in a value based marketing system will dependent upon a rather complex set of relationships between economic and biological factors. The economic factors that need to be considered are feeding costs, and the carcass quality premiums and discounts. The biological factors that affect the optimal number of days on feed include age, frame size, genetics/breed and weight.

Previous research on fed cattle pricing has considered only the revenue impacts of alternative pricing systems (Feuz, Fausti, and Wagner; Feuz; Schroeder and Graff). However, as revenue only considers price and not costs, high selling prices do not necessarily equate to high profits. As cattle have different biological endpoints to which it is economical to feed them, the best indicator of the appropriate endpoint is profit. This study will augment past studies by considering cost changes associated with the length of time cattle are on feed and the subsequent changes in carcass characteristics.

Objectives

The main objective of this paper is to increase the profitability of cattle feeding operations by determining the effect of different pricing structures on the optimal number of days on feed. To achieve this objective, a financial "closeout" model will calculate the estimated profit of slaughtering cattle on any given day using a specified pricing structure. Generating profits is a three-stage process. First, information about placement weight, days on feed, and slaughter weight is pulled from a growth model and injecting into estimated logit equations used to calculate quality grade and yield grade probabilities. Second, the resulting array of yield and quality grade probabilities, which will change with days on feed, is used to weight an array of yield and quality grade premiums and discounts. This second stage renders an expected slaughter price for a given animal on any given day. Third, weight and cost of gain information from the growth simulator and the expected slaughter price are used to calculate daily net profit levels for any given number of days on feed.

The first section of this paper discusses background information relating to animal growth and grid pricing. Next, the data, animal growth model, and logistic models used in this research are discussed. Then, the results and sensitivity analysis for the optimization problem using different pricing structures are presented. Lastly, the implications of the findings for the cattle feeding industry are considered.

Animal Growth and Grid Pricing Theory

Animal Growth Theory

In 1963, G.P. Lofgreen and W.N. Garrett introduced a system designed to measure the net energy requirements of beef cattle in the growing and finishing phases of production. The authors argue that a net energy system must differentiate net energy for maintenance requirements (NE_m) from net energy for gain requirements (NE_g) because the total net energy per unit of a feed (NE_{m+g}) varies with the level of feed. The NE_{m+g} per unit of a feed will be highest at low levels of feeding when animals are gaining weight quickly; NE_{m+g} per unit of feed decreases as feeding levels rise because feed conversion declines. In other words, this system assumes that feed will be used to satisfy maintenance requirements and intake beyond the maintenance requirement will be available for gain. Therefore, a system based on NE_m and NE_g separately will yield more accurate estimates of energy requirements.

D.G. Fox and J.R. Black used Lofgreen and Garrett's net energy system but included adjustments for factors that affect the net energy requirements of cattle. While cattle in a given pen enter the feedlot on the same day, several different factors will result in animals being fed different lengths of time and, therefore, achieving different quality and yield grades at slaughter. In addition to time, other factors including body size, stage of maturity, use of growth and feed stimulants, feed quality, and intake affect growth. All the factors that affect growth and the relationships between these factors are displayed in Figure 3.1.

Given these effects and relationships, the system used to estimate the growth and performance of feeder cattle must account and adjust for these factors. Fox and Black developed a system of continuous equations that adjust for time on feed, weight, rate of gain, frame size, breed, sex, use of growth stimulants, and the nutritional management system.

Grid Pricing

Under live weight pricing, heavier animals typically generate more revenue and profit for the feeder and producer. However, consumer demand for higher quality beef forced packers to change their buying strategies. Packers believed that grid pricing, a type of value based pricing, had the potential to improve the consistency and quality of beef they sold (Schroeder et al.). Unlike live pricing, which prices animals based on averages, grid premiums and discounts convey consumer preferences back to producers via market prices. Additionally, the intent of grid pricing is to provide producers an incentive to invest in better genetics and to encourage feeders to alter management practices (Boland, Preckel and Schinckel). Therefore, the premiums and discounts associated with grid pricing improve the likelihood that packers will receive desirable carcasses and consumers will receive the product they desire.

Grid pricing determines the values of individual carcasses by applying discounts and premiums to a base price according to quality grade, yield grade and dressed weight. The term grid refers to the matrix of premiums and discounts. The rows of the matrix consist of the USDA quality grades and the columns consist of the USDA yield grades. Most grids use the value of a Choice, Yield Grade 3 carcass weighing 550-950 pounds as the base price. Several base prices are used: weekly plant average prices, highest reported price in a specific geographic region, boxed beef cutout value, futures market price, or a negotiated price. Quality grades for steers or heifers are Prime, Choice, Select, and Standard. Quality grades, which are indicative of the eating quality of the meat, are assigned based on the amount of marbling in the ribeye and the age of the animal. Prime carcasses have more marbling so they receive premiums. As the degree of marbling in Select and Standard carcasses is less, these carcasses get discounted. Yield Grades 1 through 5 are a measure of the expected percent of boneless, closely cut trimmed retail cuts from the round, loin, rib, and chuck on a carcass weight basis. Yield grades are formula determined based on four factors: thickness of fat over the ribeye, area of the ribeye muscle, percentage of kidney, pelvic, and heart fat, and carcass weight. Carcasses with a Yield Grade of 1 or 2 have the highest percentage of lean cuts and the least amount of fat so they receive premiums. Having more fat and lower cutability, Yield Grades 4 and 5 earn discounts.

Data

Data for 467 large frame, mixed breed - primarily British and Continental - steers were obtained from Oklahoma State University's Department of Animal Science (Gill). Cattle were randomly assigned to one of 24 pens. Six pens were slaughtered after 117 days on feed with the remaining pens being slaughtered in groups of six after 131, 145, 159 days on feed. After the carcasses were chilled 36 hours, USDA graders assigned quality and yield grades.

The carcass characteristics of animals by days on feed are presented in Table 3.1. Hot carcass weight, percent low and premium choice, ribeye area, and average yield grade increased with days on feed. The percentage of Yield Grade 1 and 2 carcasses decreased over time and the percentage of Yield Grade 4 and 5 carcasses increased with days on feed.

In this study, cattle were assumed to be purchased for $86.90 per hundredweight. This is the average cost of feeder cattle weighing 700 to 800 pounds during January of 2000. Purchase prices for animals outside this weight range were multiplied by the price adjustment factors that appear in Table 3.2. The price adjustment factors used are the average price differentials for cattle sold in Nebraska between August 1999 and January 2000 (Drovers). The net energy for maintenance of the ration was assumed to be 2.21 Mcal per kilogram of dry matter, the net energy for gain of the ration was assumed to be 1.49 Mcal per kilogram of dry matter, and the dry matter of the ration is assumed to be 100%. A feed cost of $135.79 per ton was used in the base analysis. Also, one analysis used a feed price of $145.00 per ton (high) and another analysis used a feed price of $105.00 per ton (low). Additionally, the model assumed an interest rate of 8.75 percent, yardage costs at $.05 per day, an 0.93 percent death loss, a checkoff of $1 per head sold, freight costs of $1 per head, and veterinary medicine costs of $8.36 per head. Other production costs for utilities, fuel, electricity, telephone, depreciation, taxes, insurance, and hired labor were specified to total to $2 per head.

A base grid price of $113.50 per hundredweight and a constant baseline price of $68.00 per hundredweight were assumed in this analysis. The base grid price is an average boxed beef cutout value for Choice carcasses between 550 and 850 pounds. The constant baseline price is the same for all animals; it is not based on quality or yield grade and does not include any weight discounts[1]. All the prices assumed in this study were average prices reported during January 2000. Several grids were specified in this analysis. All the grids specified in this study are presented in Table 3.3 and 3.4. Grids 1 through 7, which appear in Table 3.3, are seven actual grids used by the seven major packers on November 17, 1997. Grid 7 pays high premiums for Prime but average premiums for YG1 and YG2. Grid 3 pays very little for Prime and nothing for YG1 and YG2. The other grids in this series fall somewhere in between. The NCA grid in Table 3.3 is based on the average premiums and discounts published in the *National Carcass Premiums and Discounts for Slaughter Steers and Heifers* between October 1996 and January 2000. The grids appearing in Table 3.4 are examples of the "new era" grids that provide significant premiums to Prime, Yield Grade 1 and Yield Grade 2 cattle. Four of the grids are variations of the base grid. Two of the grids narrow or widen the Choice/Select and Choice/Standard spread and the remaining two grids narrow or widen the Yield Grade 3/4 and Yield Grade 3/5 spread.

This analysis applies all the appropriate quality, yield and weight premiums or discounts to each animal without any weight or quality requirements. This appears to be the most common practice in the industry. However, some grids apply only the smallest discount and other grids only apply quality and yield premiums to carcasses within a certain weight range. In addition, there are grids that pay the same price for

Standard carcasses regardless of yield grade. Many grids require a certain percentage of Choice carcasses before any premiums are applied.

Procedures

Animal Growth

To estimate the economics of cattle feeding over time, several biological relationships need to be quantified and differences in body composition and feedstuff utilization need to be accounted for. To calculate animal growth, it is necessary to determine dry matter intake, daily gain, and the associated total cost of feeding the animal on a specific day. The animal growth (net energy) system used in this research makes use of D.G. Fox and J.R. Black's system of growth equations but modifies key parameters in the intake and daily gain functions so the growth model accurately tracks the actual performance of the cattle used in this study. Given the detailed nature of the growth model used in this study, the equations and parameters used in this research are presented in Appendix A and the Excel Visual Basic program used to grow the cattle appears in Appendix B.

Logistic Estimation for Yield and Quality Grade Classifications

Estimating cattle growth and costs using the growth model will result in each placement weight following a unique growth path to a given slaughter weight. To calculate daily revenue, it is necessary to relate a probability to each of the five yield grades and the four quality grades that an animal could achieve on a specific day. As the outcome variable (yield grade or quality grade) is a discrete variable, the estimated probabilities are generated using an ordinal logit model. Ordinal logit is a statistical model that is nonlinear in the parameters and examines the relationship between response probability and explanatory variables. The calculation of the probabilities is a two-stage process. In the first stage, the logistic procedure in SAS™ is used to estimate maximum likelihood intercept and slope parameters by regressing actual slaughter weight and total number of days on feed against the actual USDA yield grade or USDA quality grade. The basic functional forms of these logistic regression equations are:

$$
(1)\quad
\begin{aligned}
\mathit{Yield\ Grade} &= f\left[\mathit{Log}(\mathit{Slaughter\ Weight}),\ \mathit{Log}\left(\mathit{Days\ on\ Feed}^{2}\right)\right] \\
\mathit{Quality\ Grade} &= g\left[\mathit{Log}(\mathit{Slaughter\ Weight}),\ \mathit{Log}\left(\mathit{Days\ on\ Feed}^{2}\right)\right]
\end{aligned}
$$

The estimated logistic intercept and slope parameters and their associated Chi-Square values and p-values appear in Table A.3 in Appendix A. All of the estimated parameters are significant at the 5% level. A goodness of fit criterion for each model appears in Table A.4 in Appendix A. The –2 Log L criterion p-value indicates in each logistic regression the variables are jointly significant at the 5% level. Therefore, both the yield and quality grade logistic regression models are appropriate. The second stage uses the parameters estimated in the first stage and the simulated weight and days on feed, *t*, from the growth model to assign yield or quality grade probabilities. The probability prediction equations used to assign the five yield grade probabilities and four quality grade probabilities to each animal, *j*, are:

$$
(2)\quad
\begin{aligned}
GF_{i,j,t} &= Int_i + BSW * LCW_{j,t} + BDOF * LSt && \text{for } j = 1 \text{ to } 467 \\
P_{i,j,t} &= \frac{e^{GF_{i,j,t}}}{1 + e^{GF_{i,j,t}}} && \text{if } i = 1 \\
P_{i,j,t} &= \frac{e^{GF_{i,j,t}}}{1 + e^{GF_{i,j,t}}} - \frac{e^{GF_{i-1,j,t}}}{1 + e^{GF_{i-1,j,t}}} && \text{if } i = 2 \text{ to } k - 1 \\
P_{i,j,t} &= 1 - \frac{e^{GF_{i-1,j,t}}}{1 + e^{GF_{i-1,j,t}}} && \text{if } i = k
\end{aligned}
$$

where *i* is a particular yield grade (i.e. *i*=1, 2, 3, 4) or quality grade (i.e. *i*=1, 2, 3), $GF_{i,j,t}$ is a grading function, Int_i is the logistic intercept parameter estimate generated in SAS™, *BSW* is the yield grade or quality grade logistic slope estimate for the slaughter weight variable estimated in SAS™, *BDOF* is the yield grade or quality grade logistic slope estimate for the days on feed variable estimated in SAS™, $LCW_{j,t}$ is the logged current weight of animal *j* on day *t*, *LSt* is the current day on feed, t, that is squared and then logged, e=2.718282, and $P_{i,j,t}$ is the probability of animal *j* achieving a specific yield or quality grade, *i*, on day *t*. In this analysis, *k* is the maximum number of yield or quality grades so *k*=5 for yield grades and *k*=4 for quality grades.

Yield grade probabilities are calculated such that on day 1 all the animals have a 100% probability of being a Yield Grade 1. Over time, the Yield Grade 1 probability declines and the probability of attaining a Yield Grade 5 increases. This same process occurs in the quality grade probability calculation – animals initially grade Standard but over time the probability of grading Prime increases.

The expected profit on day *t* for a specific animal can be calculated using the expected yield and quality grade probabilities from Equation 2, the grids in Table 3.3 and 3.4, and the total cost of feeding and dressing percentage generated in the growth model that appears in Appendix A. The profit for an individual animal, j, on day *t* can be written mathematically as:

$$\text{(3)}\quad E\left(\pi_{j,t}\right) = \left(BGP + \sum_{x=1}^{5} \left(PYG_{x,j,t} * YG_x\right) + \sum_{y=1}^{4} \left(PQG_{y,j,t} * QG_y\right) - \left(PL_{j,t} * L\right) - \left(PH_{j,t} * H\right) - TC_{j,t} \right) * \left(BW_{j,t} * DrsPcnt_{j,t}\right)$$

where $E(\pi_{j,t})$ is the expected profit for animal *j* on day *t*, *BGP* is the base grid price for a Choice, Yield Grade 3 carcass, $PYG_{x,j,t}$ is animal *j*'s probability of attaining Yield Grade *x* on day *t* from Equation 2, YG_x is the \$/hundredweight premium/discount for Yield Grade *x*, $PQG_{y,j,t}$ is animal *j*'s probability of achieving a Quality Grade *y* on day *t* from Equation 2, QG_y is the \$/hundredweight premium/discount for Quality Grade *y*, $PL_{j,t}$ equals 1 (receives a light carcass discount on day *t*) if the hot carcass weight from Equation 8 in Appendix A is less than 5.25 hundredweight and zero otherwise[2], *L* is the light carcass discount applied to a carcass weighing under 5.25 hundredweight, $PH_{j,t}$ equals 1 (receives a heavy carcass discount on day *t*) if the hot carcass weight from Equation 8 in Appendix A is greater than 9.5 hundredweight and zero otherwise[2], *H* is the heavy carcass discount applied to a carcass weighing over 9.5 hundredweight, $TC_{j,t}$ is animal *j*'s total cost of feeding as of day *t* calculated in Equation 15 in Appendix A, $BW_{j,t}$ is animal *j*'s liveweight on day *t* from Equation 6 in Appendix A, and $DrsPcnt_{j,t}$ is animal *j*'s dressing percentage on day *t* from Equation 7 in Appendix A.

Expected profits for a specific cost and grid pricing structure are used to identify the optimal number of days on feed. Using Equation 3, the mathematical expression to identify the maximum expected profit when all 467 animals are sold on the same day, *t*, is:

(4) $$\underset{t}{Max} \sum_{j=1}^{467} \mathrm{E}\left(\pi_{j,t}\right)$$

where $E(\pi_{j,t})$ is the expected profit generated by the j th animal on day t.

Results

Days on Feed

The number of days on feed that maximize profits when all 467 animals are sold under the seven actual grids, the National Carcass Premium and Discount Average Grid, and constant baseline pricing appear in Figure 3.2. This graph suggests that the number of days cattle are on feed depends on the pricing method and the grid used. There is a significant difference in the number of days that cattle are on feed when they are sold under a grid pricing system and a constant baseline pricing system. One might expect to feed "grid" cattle longer in the hopes of earning Prime premiums; however, this research shows that cattle sold under a constant baseline pricing system will on feed longer than cattle sold in a grid pricing system. As constant baseline pricing pays an average price for all cattle without applying any premiums or discounts, feeders benefit from putting more weight on the animal. This research shows that for this given pen of cattle profits will be maximized after 200 days on feed under a constant baseline pricing system. However, these same cattle will be fed, on average, only 141 days under a grid pricing system. Feeders have an incentive to feed cattle for shorter periods because of the discounts on Yield Grade 4, Yield Grade 5, and heavy carcass animals.

The second difference is the considerable variation in the number of days on feed among the different grids. Cattle sold under Grid 7 will only be feed 131 days; however, under Grid 2 these same cattle would be fed 151 days. Grid 7 has small Select and Standard discounts but applies substantial discounts to cattle having Yield Grades 4 or 5. Grid 2 has small Yield Grade 4 and 5 discounts and large discounts for Select and Standard cattle. This finding suggests that the relationship between the Yield Grade 4 and 5 discounts and Select and Standard discounts determines the optimal number of days on feed.

A sensitivity analysis was conducted to see what changes in a specific grid will have the greatest effect on the number of days on feed. The base grid used in the base analysis is a 'new era' grid advocated by one of the largest packers. This new grid gives significant premiums to Prime cattle and moderate yield grade discounts. The first sensitivity analysis changes the Choice/Select and Choice/Standard discount spreads. When the number of Select and Standard cattle being slaughtered is large, the Choice/Select and Choice/Standard spreads will widen. Using a grid with wider spreads means that poor quality cattle receive greater discounts than under the base grid. The effects of these changes on the optimal number of days on feed appear in Figure 3.3. Cattle sold under the base grid would be feed 132 days. Increasing the Choice/Select and Choice/Standard spreads by \$9.50 and \$7.00, respectively, all else constant, causes the number of days on feed to increase to 141 days. Additionally, when the number of Select and Standard cattle being slaughtered is small, the Choice/Select and Choice/Standard spreads will narrow. Narrow spreads place small discounts on lower quality cattle; therefore, days on feed are like to decrease because there is less incentive to avoid these discounts. Decreasing the Choice/Select spread by \$2.50 and the Choice/Standard spread by \$7.00 causes in the optimal number of days on feed to decrease to 130. A rough rule that follows from these results is that the optimal number of days on feed increases 1.1 days for every dollar increase in the Choice/Select spread, ceteris paribus.

The second sensitivity analysis, which appears in Figure 3.4, changes the Yield Grade 3/4 and Yield Grade 3/5 spreads. Grids with narrow (wide) Yield Grade 3/4 and 3/5 spread grids, all else constant, place smaller (larger) discounts on low yielding carcasses. A \$5.00 increase in the Yield Grade 3/4 spread and a \$8.00 increase in the Yield Grade 3/5 spread causes the number of days on feed to decrease to 127 days. Likewise, a decrease of \$3.00 and \$8.00 in the Yield Grade 3/4 and 3/5 spreads, respectively, will result in cattle being fed 139 days. The decrease in yield grade spreads increased the length of time on feed because the gains in revenue from added weight were greater than the losses from yield grade deterioration. The rule of thumb that follows from this analysis is that every \$1 increase in the Yield Grade 3/4 price spread decreases the optimal number of day on feed, ceteris paribus, by about 1.5 days.

Figure 3.5 shows how the number of days on feed changes given high and low feed costs. While this change does not affect the grid itself, it logically has an effect on the number days animals are on feed. To maximize profits in the event of rising feed costs, feeders will not leave cattle on feed as long. If feed costs increase by $9.21 per ton, the optimal number of days on feed decreases 7 days. The opposite is true as the cost of feeding cattle decreases. If feed costs decrease $30.79 per ton, days on feed increases 5 days. Therefore, every $1 per ton increase in feed costs results in a .09 day decrease in days on feed.

Cattle Feeding Profits

This research does not focus on the absolute value of the profits; rather, it focuses on the behavior of profits over days on feed. As shown in Figure 3.6, constant baseline pricing systems cause profits to increase slowly but steadily. Unlike the relatively flat constant baseline profit curve, the base grid profit curve has sections where profits increase at an increasing rate, then increase at a decreasing rate, then stay within a narrow window for several weeks before profits begin falling. At "peak" of the base grid profit curve, there is a 2 (+/-) week window where cattle can be sold without significant changes in per head profits. During this two week period, the greatest change in per head profits is $2.00.

Behind the scenes but reflected in the profit curve is the marginal costs and revenues of feeding cattle. The marginal cost of feeding cattle is increasing all the time because of the frame size and efficiency of the cattle used in this research. As cattle go from Standard to Select to Choice, revenue and marginal revenue are increasing. However, at the beginning of the window, discounts for Yield Grade 4 and 5 carcasses take effect. From this point on, premiums for quality are less than the discounts on yield grade so marginal revenue begins decreasing. Another view of this relationship is shown in Figure 3.7.

Carcass Characteristics

Table 3.5 shows the how different grids affect the distributions of several carcass characteristics. When compared to the base grid, cattle sold under narrow Choice/Select or wide YG 3/4 grids will not be fed as long and, therefore, fewer cattle will achieve a quality grade of Choice or better. Cattle are fed for a shorter period because cattle feeders can achieve cost reductions that are larger than the changes in revenue. As cattle are fed longer under wide Choice/Select and narrow YG 3/4 grids, more cattle grade Choice or better. Constant baseline priced cattle achieve the highest percentage of Prime and Choice cattle merely because of the number of days they are on feed. During periods of high (low) feed costs, the number of cattle grading Select or Standard increases (decreases).

The effect of different grids on yield grade distributions follows the same pattern. As shown in Table 3.5, more cattle will achieve Yield Grades of 4 and 5 when priced under wide Choice/Select and narrow YG 3/4 grids. On the other hand, when compared to the base grid, the percentage of cattle with Yield Grades of 1, 2, or 3 increases under narrow Choice/Select and wide YG 3/4 grids. Constant baseline priced cattle achieve significantly high levels of Yield Grades 4 and 5. During periods of low feed costs, cattle will be fed longer and, therefore, more cattle will achieve Yield Grades 4 and 5. During high feed costs, the opposite is true.

The last carcass trait that is affected by the number of days on feed is weight. The only group to have heavy carcasses is the constant baseline priced cattle. The average weight of the 467 animals was 1,472, which explains why 37.04% of these cattle had carcass weights greater than 950 pounds. The remaining groups had weights in the high 1,200's and low 1,300's. Average weight increased with days on feed but none of these groups were classified as heavy carcasses.

Summary

Cattle have a natural physical endpoint to which it is economical to feed them. Grid pricing introduces quality grade and yield grade into the price discovery process. This research uses a growth simulation model, logistic regression, and an optimization routine in Excel to maximize expected profits and determine the effect of different pricing structures on the number of days on feed.

Several pricing methods and grid structures were used: (A) constant baseline, (B) a base grid with high Prime premiums and Yield Grade 3/4 and 3/5 discounts, (C) grids with large and small discounts for Select and Standard carcasses, and (D) grids with large and small discounts associated with Yield Grade 4 and 5 carcasses. The important effects of the pricing structures on fed cattle marketing decisions are:

- The structure of the grid, primarily the relationship between quality grade discounts and yield grade discounts, affects the number of days on feed. More specifically, large quality grade discounts and small yield grade discounts increases the number of days on feed. While small quality grade discounts and large yield grade discounts result in fewer days on feed.
- A $1 increase in the Choice/Select spread, all else constant, will cause the number of days on feed to increase about 1.1 days.
- A $1 increase in the Yield Grade 3/4 spread, all else constant, will cause days on feed to decrease by 1.5 days.
- There is a negative relationship between the number of days on feed and feed price. For every $1 per ton increase in feed price, days on feed will decline .09 days, all else constant.

Implications

Grid pricing not only brings complexity into the marketing system but it also improves pricing accuracy. As price and profit are important signals to feedlot owners to change marketing decisions, viable marketing decisions will depend on whether price incentives are present. This research indicates that adjusting days on feed is a viable marketing decision for feedlot owners. Some believe that cattle that will be sold on a grid need to be fed longer to increase the likelihood of earning Prime premiums. However, this research suggests that the length of time on feed differs depending on the grid being considered. To increase profits and achieve gains in efficiency, it appears that cattle need to be fed and targeted at specific grids. This, however, requires knowledge of each animal's growth capability and careful monitoring of carcass characteristics over the feeding period.

Future Improvements

This research is by no means exhaustive. The results are based on one pen of experimental data. Further research needs to look at the effects of breed, frame size, and environmental conditions on marketing decisions. Additionally, adjustments can be made to the energy content of the diet, the base grid price, and the purchase price of feeder cattle to see how these changes impact profitability and days on feed. Also, it may be necessary to account for imperfect knowledge/risk in predicting grades, cost of gain, etc.

Endnotes

1: The constant baseline price is for comparative purposes only. It is not intended to reflect an average cash price. Cash prices included premiums and discounts based on an order buyer's visual inspection of the animals. Therefore, cash price premiums and discounts are subjective and would be difficult to estimate given the nature of this research.

2: Mathematically, E(f(x))=f(E(x)) only if the function f is linear. In this research, the weight discount function is nonlinear so some bias could be introduced by assuming that the expected discount for weight is equal to the discount for expected weight – E(Discount(weight)) = Discount(E(weight)). The extent of the possible bias was investigated.

Weight discount probabilities were derived using a standard normal cumulative density function and the expected weight of the animal. In Excel, skewness and kurtosis tests on the weight error (actual weight at slaughter – simulated weight at slaughter) distribution validated the assumption of normality. The estimated standard deviation of the 467 weight errors, σ_{we}, is 65.18. The calculations used to determine the probability of animal j receiving a light or heavy discount on day t are:

$$PL_{j,t} = D\left(\frac{525 - SW_{j,t}}{\sigma_{we}}\right)$$

(5)

$$PH_{j,t} = 1 - D\left(\frac{950 - SW_{j,t}}{\sigma_{we}}\right)$$

where $PL_{j,t}$ is the probability of animal j receiving a light discount on day t, D is a standard normal cumulative density function, 525 is the critical carcass weight for the light carcass discount, $SW_{j,t}$ is the simulated slaughter weight of animal j on day t, σ_{we} is the standard deviation of the differences between the actual and simulated slaughter weights (i.e. weight error) of the 467 animals in the data set, $PH_{j,t}$ is the probability of animal j receiving a heavy discount on day t, and 950 is the critical carcass weight for the heavy weight discount.

However, this study assigned weight discounts based on simulated weight. This method sets $PL_{j,t}$ equal to 1 if the animal's simulated carcass weight was less than 525 pounds or zero otherwise. Likewise, $PH_{j,t}$ was set equal to 1 if the animal's simulated carcass weight was greater than 950 pounds and zero otherwise.

When results from the growth simulator using the probabilities generated in Equation 5 were compared to the results from simply assigning discounts based on simulated weight, the optimal number of days on feed decreased 2 days and total profits declined about $1,000. Given this small difference in days on feed and profits, bias introduced appears to be small.

Table 3.1 Carcass Characterisitics by Days on Feed for Cattle in Original Dataset

Characteristic	Days on Feed 117	131	145	159
Hot Carcass Weight (lb.)	755	807	541	887
Dressing Percent	62.3	63.4	63.6	64.9
Low Choice	39.47%	46.90%	53.41%	61.79%
High Choice	7.67%	7.85%	18.16%	18.34%
Ribeye Area (sq. in)	12.79	12.90	12.52	13.61
Average Yield Grade	2.78	3.17	3.59	3.70
Percent Yield Grade 1 and 2	61.55%	42.58%	22.07%	15.05%
Percent Yield Grade 4 and 5	.83%	2.63%	6.95%	17.49%

Table 3.2 Feeder Cattle Purchase Price Adjustment Factors

Purchase Weight (pounds)	Adjustment Factor
500-599	1.104
600-699	1.045
700-799	1.000
800-900	.9202
>900	.8886

Table 3.3 Seven Actual Grids in Effect on November 17, 1997 and the National Carcass Average (NCA) Premiums and Discounts Grid between October 1996 and January 2000 ($/cwt.)

Characteristic	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	NCA Grid
Quality Grade:								
Prime	4.00	6.00	3.00	8.00	6.00	3.00	10.00	5.52
Select	-9.00	-10.00	-11.00	-10.00	-9.93	-10.00	-9.00	-7.77
Standard	-19.00	-30.00	-22.00	-20.00	-19.93	-18.00	-9.00	-17.39
Yield Grade:								
1	1.00	2.00	0.00	2.00	3.00	2.00	2.00	1.70
2	0.00	2.00	0.00	1.00	1.25	1.00	1.00	0.85
4	-18.00	-10.00	-20.00	-12.00	-20.00	-12.00	-22.00	-14.66
5	-23.00	-15.00	-25.00	-17.00	-25.00	-17.00	-27.00	-19.94
Weight:								
400-500	-30.00	-25.00	-25.00	-15.00	-20.00	-14.00	-23.00	-20.99
500-550	-25.00	-15.00	-15.00	-15.00	-20.00	-12.00	-21.00	-16.91
950-1000	-10.00	-20.00	-25.00	-10.00	-20.00	-18.00	-22.00	-16.21
1000+	-25.00	-20.00	-30.00	-10.00	-20.00	-23.00	-22.00	-20.88

Table 3.4 Base 'New Era' Grid and Base 'New Era' Grid with changes in the Choice/Select and Yield Grade 3/4 Spreads ($/cwt.)

Characteristic	Base Grid	Narrow C/S Grid	Wide C/S Grid	Narrow Y3/Y4 Grid	Wide Y3/Y4 Grid
Quality Grade:					
Prime	10.00	10.00	10.00	10.00	10.00
Select	-6.50	-4.00	-16.00	-6.50	-6.50
Standard	-15.00	-19.00	-22.00	-15.00	-15.00
Yield Grade:					
1	6.50	6.50	6.50	6.50	6.50
2	2.50	2.50	2.50	2.50	2.50
4	-17.00	-17.00	-17.00	-12.00	-20.00
5	-17.00	-17.00	-17.00	-17.00	-25.00
Weight:					
400-500	-17.00	-17.00	-17.00	-17.00	-17.00
500-550	-17.00	-17.00	-17.00	-17.00	-17.00
950-1000	-17.00	-17.00	-17.00	-17.00	-17.00
1000+	-17.00	-17.00	-17.00	-17.00	-17.00

Table 3.5 Summary Statistics of Optimal Days on Feed, Yield Grade, Quality Grade, Light/Heavy Carcasses, and Average Weight for Various Pricing Methods

		Base 'New Era' Grid and Modifications						
Variable	Constant Baseline	Base	Narrow C/S Spread	Wide C/S Spread	Narrow YG 3/4	Wide YG 3/4	Base w/ High Feed Costs	Base w/ Low Feed Costs
Days on Feed	200	132	130	141	139	127	125	138
Yield Grade 1	0.21%	4.21%	4.68%	2.65%	2.93%	5.50%	6.13%	3.09%
Yield Grade 2	3.05%	35.51%	37.62%	26.66%	28.51%	40.83%	42.96%	29.46%
Yield Grade 3	26.54%	49.13%	47.58%	54.01%	53.24%	44.97%	43.07%	52.78%
Yield Grade 4	53.69%	10.14%	9.22%	15.09%	13.88%	7.94%	7.17%	13.30%
Yield Grade 5	16.50%	1.00%	0.90%	1.60%	1.44%	0.76%	0.68%	1.37%
Prime	2.48%	0.69%	0.66%	0.85%	0.81%	0.61%	0.58%	0.79%
Choice	81.19%	57.70%	56.58%	62.44%	61.43%	54.84%	53.64%	60.92%
Select	15.07%	37.13%	38.08%	33.04%	33.92%	39.53%	40.51%	34.37%
Standard	1.26%	4.47%	4.68%	3.67%	3.83%	5.02%	5.26%	3.92%
Light Carcasses	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Heavy Carcasses	37.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Average Weight	1,472	1,300	1,294	1,326	1,321	1,285	1,279	1,318

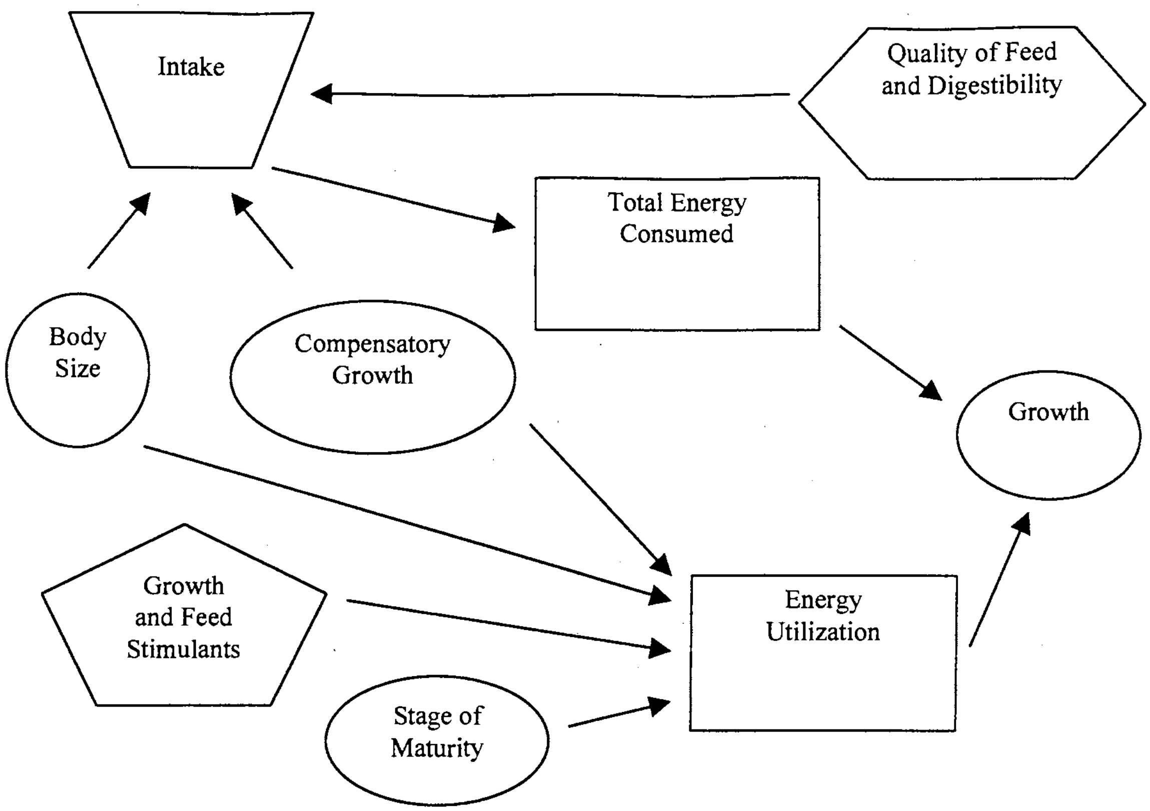

Figure 3.1 Factors affecting Cattle Growth

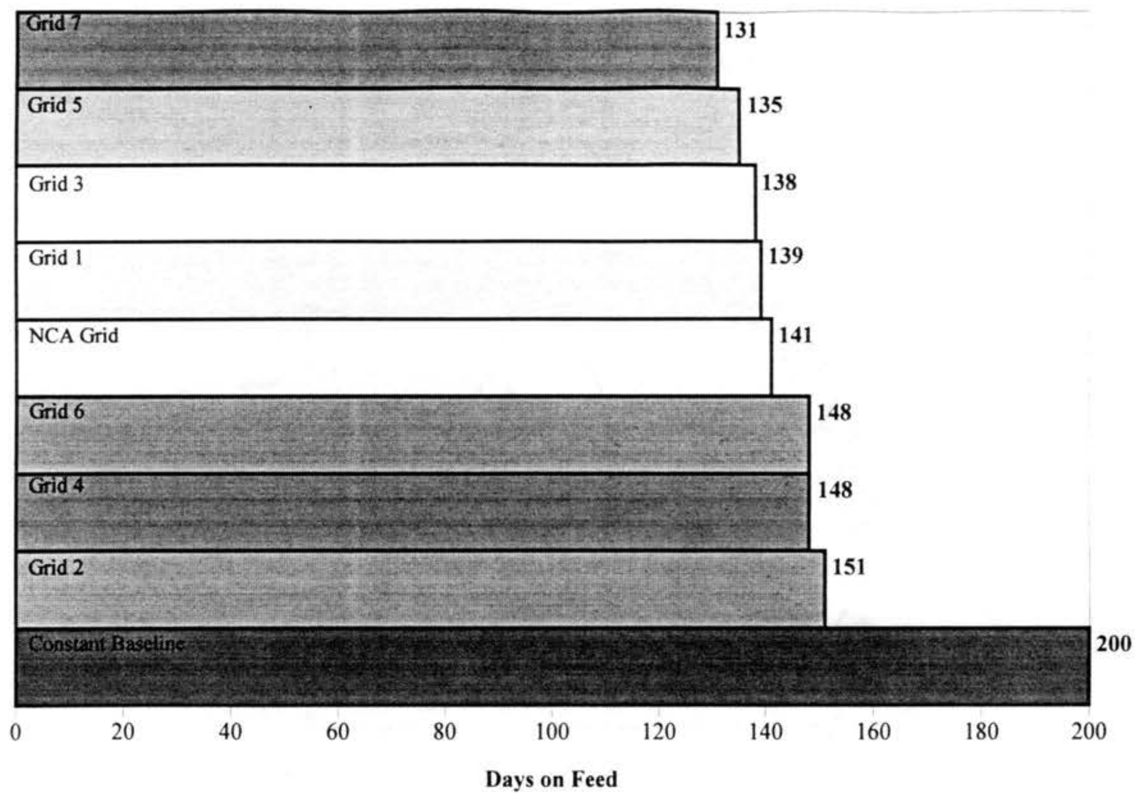

Figure 3.2 Optimal Days on Feed for the Seven Actual Grids from November 17, 1997, National Carcass Average (NCA) Premiums and Discounts Grid, and Constant Baseline Pricing

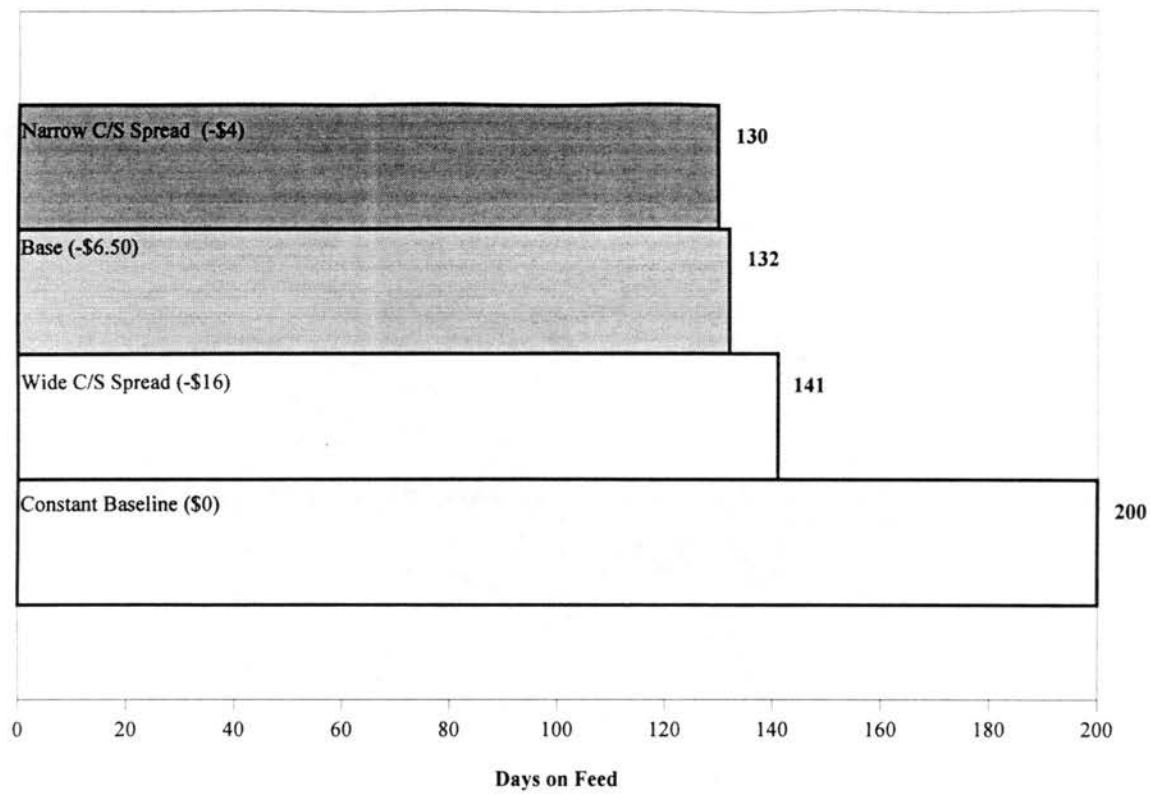

Figure 3.3 Optimal Days on Feed for Base 'New Era' Grid, Base 'New Era' Grid with Modifications to the Choice/Select Spread, and Constant Baseline Pricing

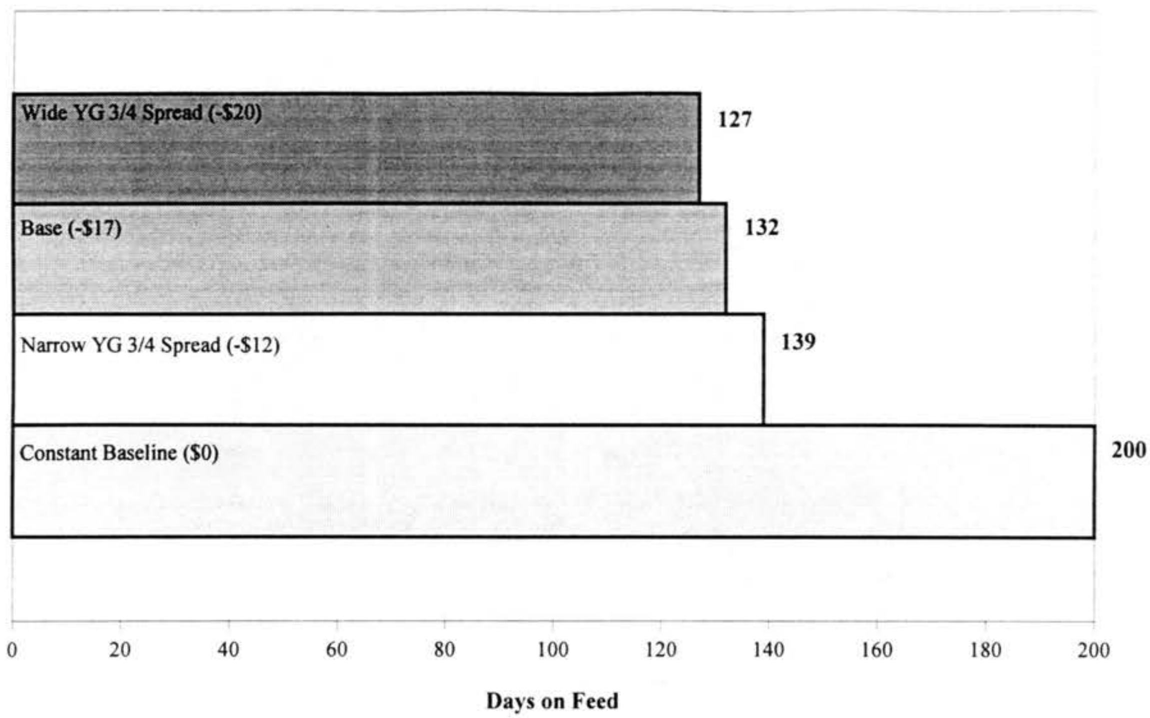

Figure 3.4 Optimal Days on Feed for Base 'New Era' Grid, 'Base 'New Era' Grid with Modifications to the Yield Grade 3/4 Spread, and Constant Baseline Pricing

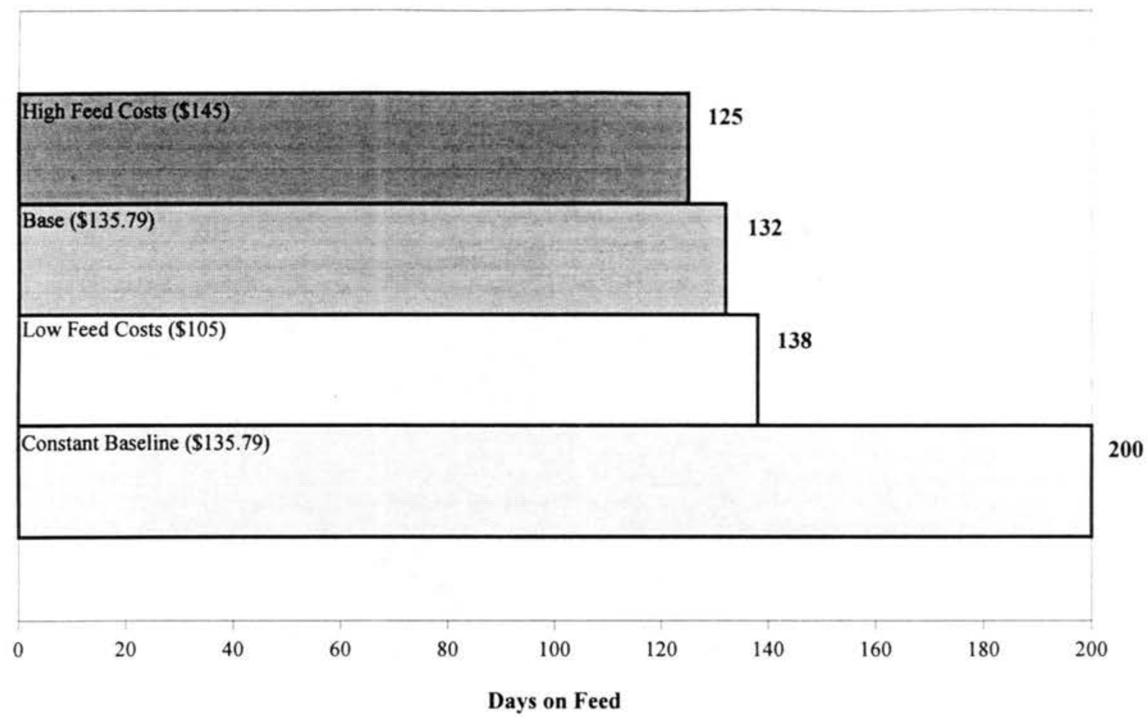

Figure 3.5 Optimal Days on Feed for Base 'New Era' Grid and Constant Baseline Pricing assuming Higher and Lower Feed Costs

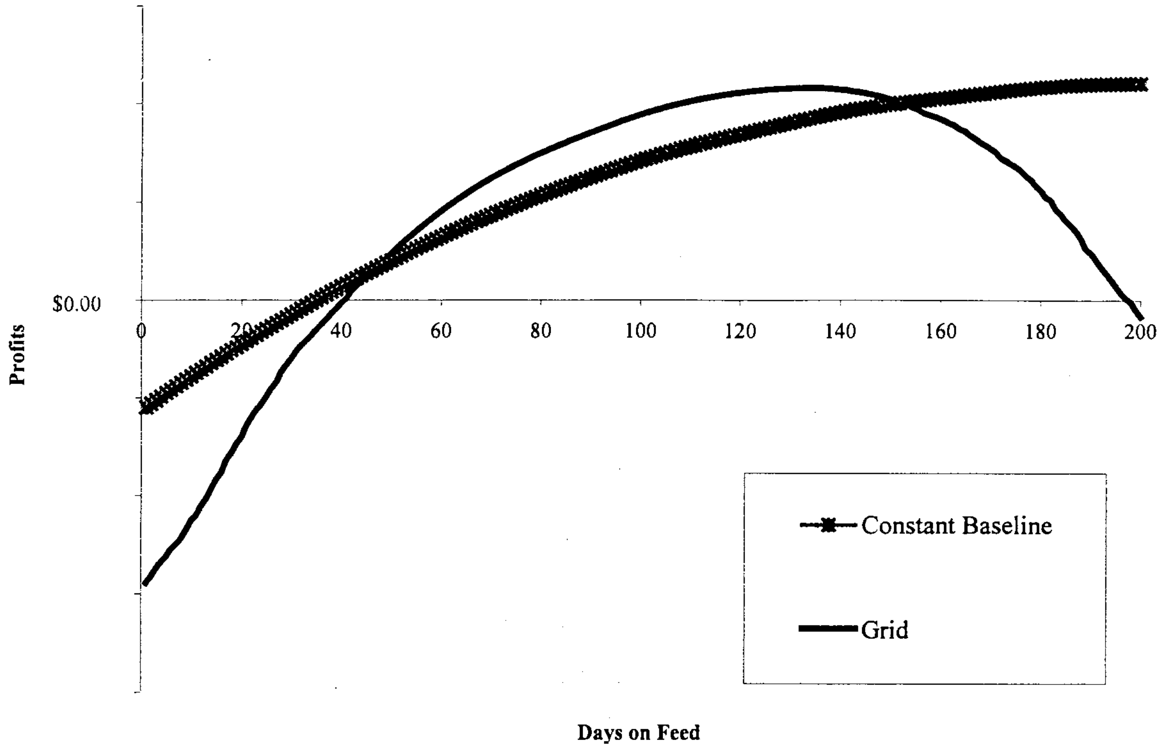

Figure 3.6 Total Profit Curves for the Base 'New Era' Grid and Constant Baseline Pricing

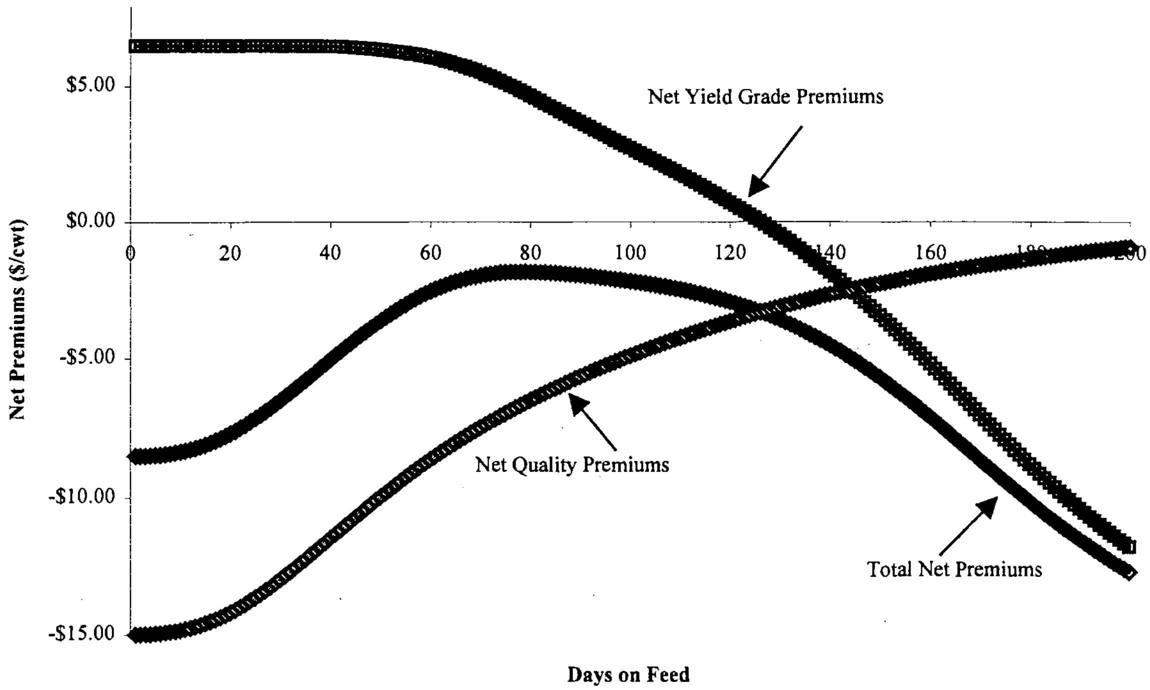

Figure 3.7 Net Yield Grade Premiums, Net Quality Grade Premiums, and Total Net Premiums for the Base 'New Era' Grid over Days on Feed

Chapter IV

Effects of Sorting and Heterogeneity on Cattle Marketing Decisions

Abstract

This research determines whether the benefits of sorting animals prior to marketing in a value based system will result in more profitable cattle feeding operations. This research uses growth models, logistic regression, and an optimization process to estimate the returns from sorting on a pen or individual basis. Pen sorting premiums of $.95 per head and individual sorting premiums of $1.18 per head were found. As the degree of heterogeneity increased, pen and individual sorting premiums increased to $6.23 per head and $6.48 per head, respectively. This research suggests that: (A) there is an incentive to sort when cattle are sold in a value based marketing system, (B) sorting premiums increase with heterogeneity, (C) the grid used to price cattle does affect the effectiveness and profitability of sorting, and (D) a simple sorting method of sorting cattle into pens based on placement weight captures 24% to 55% of the benefits more scientific methods of sorting (e.g. ultrasound).

Keywords: grid pricing, profits, animal growth, logistic regression, days on feed, heterogeneity, sorting.

Introduction

Literature suggests that increasing red meat yield, enhancing taste and tenderness, improving feedlot management, and controlling weight can lead to higher profits. Value based marketing was introduced to capture those potential profits by addressing the yield grade, quality grade, and weight issues and to encourage the consistent production of high quality beef. As value based marketing has become more prevalent in the beef industry, the objective when feeding cattle has switched from maximizing weight and total profits to maximizing total profits and optimizing the performance and value of individual cattle by considering their individual differences.

Carcass variability within a pen of cattle is the most common downfall when selling in a value based marketing system. Some say that 80 percent of the losses from selling a pen of cattle in a value based marketing system come from the bottom 20 percent of the cattle in the pen. For example, an average pen of cattle that are fed and marketed together will have (A) poor performers that inflate the cost of gain for the pen, (B) light and heavy cattle that earn significant discounts, (C) animals that grade poorly, and (D) cattle that achieve average and above average performance and carcass characteristics. Therefore, many cattle feeders, who primarily sell in a value based marketing system, are adopting more scientific and precise methods of identifying live animal carcass characteristics in order to make targeted management and marketing decisions. In the short run, identifying live animal carcass characteristics allows feeders to manage and market animals such that discounts are minimized or avoided and the profit potential of each animal is maximized. Long run management decisions use performance and carcass data to improve the quality and uniformity of the cattle being raised and the efficiency of the entire industry.

Sorting in a Value Based Marketing System

In a value based marketing system, the management and marketing decision-making process is an act of balancing weight, carcass quality, and cost of gain. Animal value will increase as weight increases as long as the carcass does not grade poorly or become a heavy carcass. Increasing quality grades will lead to increases in an animal's value if the animal does not become over fat or have rapidly declining yield grades. Cost of gain will increase steadily over time as cattle become heavier and convert feed less efficiently. Eventually, the cost per pound of gain will be greater than the return on that pound of gain. In the end, if the animal is sold before it reaches its biological and economic endpoint, the feeder will lose potential profits from higher quality grades, cost efficient gains, or both. If an animal is sold after its optimal endpoint, the feeder loses profits to yield grade and weight discounts, and cost of gain increases.

Sorting cattle during the feeding process will result in pens of cattle that are uniform in weight, body composition, growth patterns, and degree of finish. Grouping cattle based on these similarities makes it easier for feedlots to feed and market cattle at their optimal endpoint. Thus, when selling animals on a carcass basis in a value based marketing system, sorting should minimize yield grade, quality grade and carcass weight discounts. In addition to increased profitability, sorting will allow feeders can improve feeding efficiency and the quality of cattle produced in the United States.

There are many sorting methods that feeders can use to market cattle when they are biologically and economically ready or to identify outlier cattle for special or early marketing to avoid discounts. Animals can be grouped into homogenous pens using visual inspection and weight when they first come into the feedyard. Some feeders may re-sort after so many days on feed or when the animals are re-implanted. Another sorting method involves using weight, fat and marbling scores based on ultrasound results, and average daily gain since last weighing to calculate projected gain. Based on the projected gain, ultrasound imaging software packages create profitability curves to forecast when animals will earn the highest profit. The appropriate sorting method will depend on the feedyard's manpower, pen space/capacity, and desire to co-mingle cattle.

By selling cattle at their individual end points, feeders can provide packers with the quality of cattle they desire. In the 1995 National Beef Quality Audit, packers wanted at least 63 percent of the carcasses they purchased to grade Choice. However, only 47 percent of the unsorted carcasses that feeders were delivering graded Choice. By sorting cattle into homogenous pens, one 18,000 head commercial feedyard in Texas was able to consistently sell pens of cattle that graded 64 percent Choice.

Very little research has been done in the area of sorting and its effects on cattle feeding profits and marketing decisions. Much of the research that has been done looked at the economic benefits of adopting an ultrasound sorting system (Koontz et. al.; Brethour; Houghton and Turlington). Koontz et. al found returns to ultrasound sorting between $11 and $25 per head depending on the number of pens cattle are sorted into. Literature published by several alliances indicates that by sorting cattle they can achieve higher selling prices and reductions in feeding costs. They claim that their systems can capture up to $30 per head of added profit by selling cattle that have been fed to their individual optimum in a value based marketing system. The research reported here uses a simple sorting technique based on weight that is currently used by cattle feeders to quantify the returns to sorting.

Objectives

The three objectives of this research are to (A) determine the economic potential of sorting cattle when they are sold in a value based marketing system, (B) identify the effects of heterogeneity on sorting premiums, and (C) identify the effect of grid structure on the returns to sorting. To achieve each of these objectives, this research uses growth models, logistic regression, and an optimization process to identify the effects of sorting on the optimal number of days on feed, carcass characteristics, and profits when cattle are grown and marketed in three different systems. To study the effects of heterogeneity on sorting premiums, each system is re-analyzed using cattle with more heterogeneous placement weights. The effect of grid structure on returns to sorting will be identified by comparing the returns to sorting, days on feed, and carcass characteristics under the base grid, which offers high premiums and average discounts, to those under a low paying grid having low premiums and high discounts.

The first section of this paper discusses background information relating to animal growth and grid pricing. Next, the data, animal growth model, and logistic model used in this research are discussed. Last, the results and implications of these findings for the cattle feeding industry are considered.

Animal Growth and Grid Pricing Theory

Animal Growth Theory

In 1963, G.P. Lofgreen and W.N. Garrett introduced a system designed to measure the net energy requirements of beef cattle in the growing and finishing phases of production. The authors argue that a net energy system must differentiate net energy for maintenance requirements (NE_m) from net energy for gain requirements (NE_g) because the total net energy per unit of a feed (NE_{m+g}) varies with the level of feed. The NE_{m+g} per unit of a feed will be highest at low levels of feeding when animals are gaining weight quickly; NE_{m+g} per unit of feed decreases as feeding levels rise because feed conversion declines. In other words, this system assumes that feed will be used to satisfy maintenance requirements and intake beyond the maintenance requirement will be available for gain. Therefore, a system based on NE_m and NE_g separately will yield more accurate estimates of energy requirements.

D.G. Fox and J.R. Black used Lofgreen and Garrett's net energy system but included adjustments for factors that affect the net energy requirements of cattle. While cattle in a given pen enter the feedlot on the same day, several different factors will result in animals being fed different lengths of time and, therefore, achieving different quality and yield grades at slaughter. In addition to time, other factors including body size, stage of maturity, use of growth and feed stimulants, feed quality, and intake affect growth. All the factors that affect growth and the relationships between these factors are displayed in Figure 3.1.

Given these effects and relationships, the system used to estimate the growth and performance of feeder cattle must account and adjust for these factors. Fox and Black developed a system of continuous equations that adjust for time on feed, weight, rate of gain, frame size, breed, sex, use of growth stimulants, and the nutritional management system.

Grid Pricing

Under live weight pricing, heavier animals typically generate more revenue and profit for the feeder and producer. However, consumer demand for leaner and higher quality beef forced packers to change their buying strategies. Packers believed that grid pricing, a type of value based pricing, had the potential to improve the consistency and quality of beef they sold (Schroeder et al.). Unlike live pricing, which prices animals based on averages, grid premiums and discounts convey consumer preferences back to producers via market prices. Additionally, the intent of grid pricing is to provide producers an incentive to invest in better genetics and to encourage feeders to alter management practices (Boland, Preckel and Schinckel). Therefore, the premiums and discounts associated with grid pricing improve the likelihood that packers will receive desirable carcasses and consumers will receive the product they desire.

Grid pricing determines the values of individual carcasses by applying discounts and premiums to a base price according to quality grade, yield grade and dressed weight. The term grid refers to the matrix of premiums and discounts. The rows of the matrix consist of the USDA quality grades and the columns consist of the USDA yield grades. Most grids use the value of a Choice, Yield Grade 3 carcass weighing 550-950 pounds as the base price. Several base prices are used: weekly plant average prices, highest reported price in a specific geographic region, boxed beef cutout value, futures market price, or a negotiated price. Quality grades for steers or heifers are Prime, Choice, Select, and Standard. Quality grades, which are indicative of the eating quality of the meat, are assigned based on the amount of marbling in the ribeye and the age of the animal. Prime carcasses have more marbling so they receive premiums. As the degree of marbling in Select and Standard carcasses is less, these carcasses get discounted. Yield Grades 1-5 are the expected percent of boneless, closely cut trimmed retail cuts from the round, loin, rib, and chuck on a carcass weight basis. Yield grades are formula determined based on four factors: thickness of fat over the ribeye, area of the ribeye muscle, percentage of kidney, pelvic, and heart fat, and carcass weight. Carcasses with a Yield Grade 1 or 2 have the highest percentage of lean cuts and the least amount of fat so they receive premiums. Having more fat and lower cutability, Yield Grades 4 and 5 earn discounts.

Data

Data for 467 large frame, mixed breed - primarily British and Continental - steers were obtained from Oklahoma State University's Department of Animal Science (Gill). Cattle were randomly assigned to one of 24 pens. Six pens were slaughtered after 117 days on feed with the remaining pens being slaughtered in groups of six after 131, 145, 159 days on feed. After the carcasses were chilled 36 hours, USDA graders assigned quality and yield grades.

The carcass characteristics of animals by days on feed are presented in Table 4.1. Hot carcass weight, percent low and premium choice, ribeye area, and average yield grade increased with days on feed. The percentage of Yield Grade 1 and 2 carcasses decreased over time and the percentage of Yield Grade 4 and 5 carcasses increased with days on feed.

In this study, cattle were assumed to be purchased for $86.90 per hundredweight. This is the average cost of feeder cattle weighing 700 to 800 pounds during January of 2000. Purchase prices for animals outside this weight range were multiplied by the price adjustment factors that appear in Table 4.2. The price adjustment factors used are the average price differentials for cattle sold in Nebraska between August 1999 and January 2000 (Drovers). The net energy for maintenance of the ration was assumed to be 2.21 Mcal per kilogram of dry matter, the net energy for gain of the ration was assumed to be 1.49 Mcal per kilogram of dry matter, and the dry matter of the ration is assumed to be 100%. A feed cost of $125 per ton was used in the base analysis. Additionally, the model assumed an interest rate of 8.75 percent, yardage costs at $.05 per day, an 0.93 percent death loss, a checkoff of $1 per head sold, freight costs of $1 per head, and veterinary medicine costs of $8.36 per head. Other production costs for utilities, fuel, electricity, telephone, depreciation, taxes, insurance, and hired labor were specified to total to $2 per head.

A base grid price of $113.50 per hundredweight, which is an average boxed beef cutout value for Choice carcasses between 550 and 850 pounds reported during January 2000. The two grids used in this study appear in Table 4.3. The base grid is a high paying grid and is an example of the "new era" grids that provide significant premiums to Prime, Yield Grade 1, and Yield Grade 2 cattle. The second grid pays much less for Prime, Yield Grade 1, and Yield Grade 2 cattle and applies more severe discounts to cattle with low yield grades and/or light/heavy carcasses.

This analysis applies all the appropriate quality, yield and weight premiums or discounts to each animal without any weight or quality requirements. This appears to be the most common practice in the industry. However, some grids apply only the smallest discount and other grids only apply quality and yield premiums to carcasses within a certain weight range. In addition, there are grids that pay the same price for Standard carcasses regardless of yield grade. Many grids require a certain percentage of Choice carcasses before any premiums are applied.

Procedures

Animal Growth

To estimate the economics of cattle feeding over time, several biological relationships need to be quantified and differences in body composition and feedstuff utilization need to be accounted for. To calculate animal growth, it is necessary to determine dry matter intake, daily gain, and the associated total cost of feeding the animal on a specific day. The animal growth (net energy) system used in this research makes use of

D.G. Fox and J.R. Black's system of growth equations but modifies key parameters in the intake and daily gain functions so the growth model accurately tracks the actual performance of the cattle used in this study. Given the detailed nature of the growth model used in this study, the equations and parameters used in this research are presented in Appendix A and the Excel Visual Basic program used to grow the cattle appears in Appendix B, C, and D.

Logistic Estimation for Yield and Quality Grade Classifications

Estimating cattle growth and costs using the growth model will result in each placement weight following a unique growth path to a given slaughter weight. To calculate daily revenue, it is necessary to relate a probability to each of the five yield grades and the four quality grades that an animal could achieve on a specific day. As the outcome variable (yield grade or quality grade) is a discrete variable, the estimated probabilities are generated using an ordinal logit model. Ordinal logit is a statistical model that is nonlinear in the parameters and examines the relationship between response probability and explanatory variables. The calculation of the probabilities is a two-stage process. In the first stage, the logistic procedure in SAS™ is used to estimate maximum likelihood intercept and slope parameters by regressing actual slaughter weight and total number of days on feed against the actual USDA yield grade or USDA quality grade. The basic functional forms of these logistic regression equations are:

$$(1)\quad \begin{aligned} &Yield\ Grade = f\left[Log(Slaughter\ Weight), Log\left(Days\ on\ Feed^2\right)\right] \\ &Quality\ Grade = g\left[Log(Slaughter\ Weight), Log\left(Days\ on\ Feed^2\right)\right] \end{aligned}$$

The estimated logistic intercept and slope parameters and their associated Chi-Square values and p-values appear in Table A.3 in Appendix A. All of the estimated parameters are significant at the 5% level. A goodness of fit criterion for each model appears in Table A.4 in Appendix A. The –2 Log L criterion p-value indicates in each logistic regression the variables are jointly significant at the 5% level. Therefore, both the yield and quality grade logistic regression models are appropriate. The second stage uses the parameters estimated in the first stage and the simulated weight and days on feed, *t*, from the growth model to assign yield or quality grade probabilities. The probability prediction equations used to assign the five yield grade probabilities and four quality grade probabilities to each animal, j, are:

$$(2)\quad \begin{aligned}
GF_{i,j,t} &= Int_i + BSW * LCW_{j,t} + BDOF * LSt && \textit{for } j = 1 \textit{ to } 467\\
P_{i,j,t} &= \frac{e^{GF_{i,j,t}}}{1 + e^{GF_{i,j,t}}} && \textit{if } i = 1\\
P_{i,j,t} &= \frac{e^{GF_{i,j,t}}}{1 + e^{GF_{i,j,t}}} - \frac{e^{GF_{i-1,j,t}}}{1 + e^{GF_{i-1,j,t}}} && \textit{if } i = 2 \textit{ to } k - 1\\
P_{i,j,t} &= 1 - \frac{e^{GF_{i-1,j,t}}}{1 + e^{GF_{i-1,j,t}}} && \textit{if } i = k
\end{aligned}$$

where i is a particular yield grade (i.e. i=1, 2, 3, 4) or quality grade (i.e. i=1, 2, 3), $GF_{i,j,t}$ is a grading function, Int_i is the logistic intercept parameter estimate generated in SAS™, *BSW* is the yield grade or quality grade logistic slope estimate for the slaughter weight variable estimated in SAS™, *BDOF* is the yield grade or quality grade logistic slope estimate for the days on feed variable estimated in SAS™, $LCW_{j,t}$ is the logged current weight of animal j on day t, *LSt* is the current day on feed, t, that is squared and then logged, e=2.718282, and $P_{i,j,t}$ is the probability of animal j achieving a specific yield or quality grade, i, on day t. In this analysis, k is the maximum number of yield or quality grades so k=5 for yield grades and k=4 for quality grades.

Yield grade probabilities are calculated such that on day 1 all the animals have a 100% probability of being a Yield Grade 1. Over time, the Yield Grade 1 probability declines and the probability of attaining a Yield Grade 5 increases. This same process occurs in the quality grade probability calculation – animals initially grade Standard but over time the probability of grading Prime increases.

The expected profit on day t for a specific animal can be calculated using the expected yield and quality grade probabilities from Equation 2, the grids in Table 4.3, and the total cost of feeding and dressing percentage generated in the growth model that appears in Appendix A. The profit for an individual animal, j, on day t can be written mathematically as:

$$
(3) \quad E(\pi_{j,t}) = \left(BGP + \sum_{x=1}^{5} \left(PYG_{x,j,t} * YG_x\right) + \sum_{y=1}^{4} \left(PQG_{y,j,t} * QG_y\right) - \left(PL_{j,t} * L\right) - \left(PH_{j,t} * H\right) - TC_{j,t} \right) * \left(BW_{j,t} * DrsPcnt_{j,t}\right)
$$

where $E(\pi_{j,t})$ is the expected profit for animal j on day t, BGP is the base grid price for a Choice, Yield Grade 3 carcass, $PYG_{x,j,t}$ is animal j's probability of attaining Yield Grade x on day t from Equation 2, YG_x is the \$/hundredweight premium/discount for Yield Grade x, $PQG_{y,j,t}$ is animal j's probability of achieving a Quality Grade y on day t from Equation 2, QG_y is the \$/hundredweight premium/discount for Quality Grade y, $PL_{j,t}$ equals 1 (receives a light carcass discount on day t) if the hot carcass weight from Equation 8 in Appendix A is less than 5.25 hundredweight and zero otherwise[1], L is the light carcass discount applied to a carcass weighing under 5.25 hundredweight, $PH_{j,t}$ equals 1 (receives a heavy carcass discount on day t) if the hot carcass weight from Equation 8 in Appendix A is greater than 9.5 hundredweight and zero otherwise[1], $TC_{j,t}$ is animal j's total cost of feeding as of day t calculated in Equation 15 in Appendix A, $BW_{j,t}$ is animal j's liveweight on day t from Equation 6 in Appendix A, and $DrsPcnt_{j,t}$ is animal j's dressing percentage on day t from Equation 7 in Appendix A.

Expected profits for a specific cost and grid pricing structure are used to identify the optimal number of days on feed. Using Equation 3, the mathematical expression to identify the maximum expected profits when all 467 animals are sold on the same day, t, is:

$$
(4) \quad \underset{t}{Max} \sum_{j=1}^{467} E\left(\pi_{j,t}\right)
$$

where $E(\pi_{j,t})$ is the expected profit generated by the j th animal on day t.

The mathematical expression used to identify the maximum expected profits for each of the p pens cattle are sorted into at placement is:

$$
(5) \quad \underset{t}{Max} \sum_{j=1}^{J} E\left(\pi_{j,t}\right)
$$

where $E(\pi_{j,t})$ is the expected profit for the j th animal on day t, and J is the total number of animals in a particular pen.

The mathematical expression used to identify maximum expected profits when cattle are sold on an individual basis becomes:

$$\max_{t} E\left(\pi_{j,t}\right) \tag{6}$$

where $E(\pi_{j,t})$ is the expected profit generated by the j th animal on day t.

Sorting Systems

To identify the returns to sorting , this research grows in markets cattle in three different systems. System 1 sells an unsorted pen containing all 467 animals on the grid when profits for the entire pen are maximized. System 2 sorts the 467 animals into 4 weight groups/pens based on their placement weights. As this system creates pens of animals having similar growth patterns (weight, yield grade, quality grade), individual profits generated by each animal within a pen should peak on or near the same day. Each pen is then sold when its total grid profits are maximized. In System 3, each animal is sold on the grid when its individual grid profit is maximized. This last system is obviously not feasible due to the labor and pen requirements but it should provide a basis of comparison for the pen sorting done in System 2.

Generating Heterogenous Animals

A dataset of 467 animals is generated using the mean and standard deviation of the original dataset. The randomly generated distribution of placement weights in the generated dataset has a standard deviation that is twice the size of the standard deviation of the original dataset. The average placement weight in the generated dataset is equal to the average placement weight in the original dataset. With a greater variation in cattle placement weights, the population of cattle in the generated dataset is more heterogeneous than the original dataset and can be compared to the original to determine what effect heterogeneity has on days on feed and profits when cattle are sorted.

Results

The first section determines whether sorting by placement weight pays and what effects sorting has on the number of days on feed, carcass characteristics, and profits. Once the issue of returns to sorting has been addressed, the second section will present the effects of heterogeneity across the different sorting systems. The last section discusses how changing grid premiums and discounts affect the returns to sorting and the optimal number of days on feed.

NOTE: Throughout the results section, the sorting systems and scenarios are labeled as follows:

- N: cattle are not sorted and all animals are sold on the same day
- P: cattle are sorted into pens on day 0 based on their placement weight
- I: cattle are sorted and sold individually
- 6-9: refers to a pen containing animals within a specific one hundred pound interval based on placement weight – for example, pen 8 contains all animals with placement weights between 800 and 899 pounds on day 0
- the base grid is the high paying grid used to price animals unless the label contains an 'L' which indicates that the low paying grid was used
- GW2: generated dataset where the standard deviation of the placement weight distribution is twice the size of the standard deviation of the placement weights in the original dataset

Sorting

The main motivation to sort cattle is to avoid the discounts generated by outlier cattle – too heavy, too light, etc. It seems logical that feeders will attempt to grow cattle a little longer in the hopes of getting a Choice Quality Grade or better without incurring weight discounts. Figure 4.2 shows that the number of days on feed can differ by 1 day between the different sorting systems. When cattle are not sorted (N), profits are maximized after 131 days on feed. Both sorting into pens using placement weight (P) and individual sorting (I) increase the average number of days on feed. Animals in both the pen and individual sorting systems are fed an average of 132 days. One may correctly expect the cattle in an individual sorting system to be fed longer than those in a pen sorting system. The reason for this discrepancy is that the number of days on feed reported for the individual system is an average over all animals. When the maximum and minimum number of days between the two systems is compared, the individual sorting system leaves some animals on feed longer.

In addition to showing an increased in the number of days on feed, Figure 4.2 also shows that pen and individual sorting systems increase per head profits. Selling all cattle on the same day results in per head profits of $10.75. Cattle that are sorted into pens achieve an average profit of $11.70 per head. An average per head profit of $11.93 can be realized when animals are sold individually. With pen sorting premiums of $.95 per head and individual sorting premiums of $1.18 per head, pen sorting captures more than 98% of the benefit of individual sorting.

The carcass characteristics of animals sold in the three sorting systems, which appear in Figure 4.3 and Tables 4.4-4.6, provide some insight into why sorting affects profits. Animals sold in the pen and individual sorting systems achieve higher yield and quality grades without incurring overweight discounts. For example, when all animals are sold on the same day, 46.75% achieve a Yield Grade 3 and 56.88% grade Choice. The pen sorting system allows 49.46% of the animals to achieve Yield Grade 3 and 57.36% to grade Choice. Sorting on an individual basis enables 49.59% and 57.46% of the animals to achieve Yield Grade 3 and Choice, respectively.

There appears to be a small incentive to sort cattle. First, sorting captures about $1 of lost per head profits. Second, the quality of cattle being sold improves with better management of individual animals. This improvement occurs because feeders avoid over- and underfeeding animals and the number of animals with poor yield and quality grades is smaller. Third, the change in the grading distributions results in a smaller number of cattle receiving discounts so the feeders realizes a higher profit per head.

Sorting at Pen Level

To better understand the global effects of sorting on profits and management decisions, it is helpful to compare the impacts of sorting across different groups of cattle. Figure 4.4 contrasts the non-sorting system and the individual sorting system across animals that have been grouped into 100 pound intervals based on their placement weight. For example, Pen 6 (e.g. N-6 or I-6) contains animals with placement weights between 600 and 699 pounds. Likewise, Pen 7 (e.g. N-7 or I-7) contains animals with initial weighs ranging from 700 to 799 pounds. Figure 4.4 shows that cattle in the extreme weight intervals (Pen

6 and Pen 9) experience the greatest increase in per head profits when animals are sorted individually. When animals initially weighing 600-699 pounds are sorted individually, per head profits increase $5.85. Most of this increase in profits is explained by the 20 day increase in days on feed when this pen is sorted (see Table 4.4 and 4.6). An increased number of days on feed enable a greater percentage of these cattle to achieve a Choice Quality Grade (60.9% vs. 49.9%). Cattle with placement weights of 900-999 pounds gain $4.56 in per head profits despite a decline in the percentage of cattle that grade Choice. When animals are not sorted, cattle with 900-999 placement weights will be on feed for 131 days; however, with individual sorting, animals in Pen 9 are only fed 116 days, on average. This 15 day decrease in the number of days on feed prevents yield grade degradation. As yield grade degradation occurs at a faster rate than quality grade improvement, fewer days on feed allows these animals to maintain higher prices. There were not any significant changes in profits or grading between the two sorting systems for cattle with placement weights of 700-799 and 800-899. Most likely, this lack of change occurs because individually sorted animals in these weight ranges are on feed for approximately the same number of days as they would be if sorting had not occurred. Thus, there appears to be a common dynamic at work when growing and sorting cattle. Overfeeding and underfeeding result in significant discounts; therefore, by sorting cattle, feeders avoid marketing animals after a non-optimal number of days on feed. It is of interest to note that feeding animals longer and preventing the underfeeding of cattle is more profitable than reducing the number of days on feed and increasing the likelihood of overfeeding cattle.

Grid Effects

Given the number of grids currently being offered, it is important to understand how different grids affect sorting and management decisions. For simplicity, the base grid, which was used in the previous analyses, is a grid that applies high premiums and average discounts. It will be compared to a low paying grid that has low premiums and high discounts.

The longer cattle are fed the more likely they are to grade Choice or Prime and earn premiums. However, more days on feed increases the likelihood of earning discounts because yield grades are declining. The grid will determine the number of days on feed that balance this quality grade-yield grade tradeoff. The low paying grid in this analysis is typical of most grids in that the (A) quality grade discounts are comparable to the yield grade discounts and (B) quality grade premiums are greater than the yield grade premiums. Therefore, when faced with a low paying grid, feeders feed cattle longer in the hopes of moving the cattle out of the Select and Standard Quality Grades but quit before the yield grade discounts and cost of gain exceed any gains from quality improvement.

Figure 4.5 compares the days on feed for the three different sorting systems and the two grids. In all cases, the average days on feed increases when a low paying grid is being used. As there is not a clear signal about when to market animals, the above finding comes into play - losses from underfeeding are greater than those from overfeeding – so animals are fed as long as possible but are taken off feed before significant yield grade deterioration occurs. In both the pen and individual sorting systems, the low paying grid results in a greater percentage of animals with a Yield Grade 4 and Choice Quality Grade.

As shown in Table 4.7, the average profit per head is negative despite the increases in weight when a low paying grid is used. Behind the scenes, cost of gain is increasing rapidly with more days on feed. The combined effect of the yield grade discounts and an increasing cost of gain cause the low paying grid to generate negative profits. Despite the negative profits, the pen and individual sorting systems have slightly "less negative" per head profits so there is an incentive to sort when selling cattle under a low paying grid. The pen sorting system achieves sorting premiums of $1.05 and individual per head sorting premiums total $1.48.

Therefore, the grid used does have an effect on management decisions. The relationship between quality and yield discounts seems to determine when cattle need to be taken off feed. Also, while a higher paying grid will realize higher per head sorting premiums, there is an incentive to sort even under a low paying grid because sorting enables a feeder to minimize losses due to yield grade degradation.

Heterogeneity

The base dataset used in this study was a set of cattle purchased for the purpose of doing a serial slaughter study. Hence, an effort was made to get a homogeneous set of cattle. To measure the impact of heterogeneity and to consider a case more typical of the industry, a generated dataset with twice the variability in placement weight will be used.

Figure 4.6 indicates that increasing heterogeneity is accompanied by an increasing number of days on feed in the pen and individual sorting systems. This is logical because heterogeneity implies that the tails of the weight distribution are widening. Lighter (Heavier) weights will require more (less) days on feed to reach the optimal marketing date. Given the results reported above that losses from underfeeding are greater than those from overfeeding, longer days on feed will ensure that the more diverse population of cattle has time to reach an optimum.

Increasing levels of heterogeneity results in steadily increasing benefits to sorting on either a pen or individual basis. Given extreme heterogeneity (GW2), profitability drops 27.6 percent when no sorting is done but both pen and individual sorting profits increase over 19 percent. Both these changes allow per head returns to pen (individual) sorting to increase to $6.24 ($6.49). As sorting premiums increase more than fourfold, the incentive to sort increases dramatically when cattle are more heterogeneous.

Summary

Until recently, most of the cattle marketed were sold in large pens for an average price. Marketing cattle based on averages largely ignores the significant differences in carcass characteristics of individual animals within a pen. By ignoring these individual differences, average pricing resulted in some cattle being sold for more than they are worth and other cattle not generating a fair return. With the introduction of value based marketing, more cattle are being sold on an individual basis and, therefore, there is an increased reliance on sorting.

This research indicates that homogeneous cattle sorted by placement weight into 100 pound weight categories (i.e. sorting into pens) resulted in a $.95 increase in per head profits. Sorting on an individual basis so that each animal is sold at an optimum point resulted in an increase in per head profits of $1.18. The benefits of sorting depend on the placement weight of animals. Those animals on the extremes of the weight distribution benefit the most from sorting. By individually sorting these 'outlier' cattle, feeders can achieve gains in per head profits of $4.56 (heavy placement weights) to $5.85 (light placement weights). The grid animals are sold under has an impact on the returns to sorting. When cattle are sold under a low paying grid, sorting premiums increase to $1.05 and $1.48 in the pen and individual sorting systems, respectively. The degree of heterogeneity has the greatest impact on sorting premiums. When more heterogeneous cattle are fed and sold under the base grid, sorting premiums increase to over $6.24 per head in a pen sorting system and $6.49 per head in an individual sorting system.

Other research suggests that more scientific methods of sorting after placement achieve higher returns to sorting – from $11 to $25 per head. The findings from this research indicate that sorting relatively homogeneous cattle at placement adds very little to profits. However, given a level of heterogeneity similar to industry conditions, returns to sorting of more than $6 per head were estimated for this simplistic placement weight sorting method. On a relative scale, the simplistic sorting method premiums of more than $6 per head appear to be consistent with the ultrasound premium findings.

Implications

This research suggests that sorting by placement weight does result in higher profits when cattle are sold in a value based marketing system. However, this research does not take directly account for the additional costs of labor and the performance effect of commingling cattle. The true cost of sorting is difficult to estimate but some feeders who sort cattle using ultrasound technology estimate that the cost of sorting ranges between $4 and $5 a head. Sorting cattle at placement into 100 pound weight categories should be less costly than ultrasound. Additionally, a simple sorting method based on placement weight avoids any economic and biological losses in performance that are associated with sorting and commingling cattle after a significant time on feed. Therefore, sorting heterogenous cattle at placement is a viable approach to marketing cattle at an optimal point.

Endnotes

1: Mathematically, E(f(x))=f(E(x)) only if the function f is linear. In this research, the weight discount function is nonlinear so some bias could be introduced by assuming that the expected discount for weight is equal to the discount for expected weight – E(Discount(weight)) = Discount(E(weight)). The extent of the possible bias was investigated.

Weight discount probabilities were derived using a standard normal cumulative density function and the expected weight of the animal. In Excel, skewness and kurtosis tests on the weight error (actual weight at slaughter – simulated weight at slaughter) distribution validated the assumption of normality. The estimated standard deviation of the 467 weight errors, σ_{we}, was 65.18. The calculations used to determine the probability of animal j receiving a light or heavy discount on day t are:

(7)

$$PL_{j,t} = D\left(\frac{525 - SW_{j,t}}{\sigma_{we}}\right)$$

$$PH_{j,t} = 1 - D\left(\frac{950 - SW_{j,t}}{\sigma_{we}}\right)$$

where $PL_{j,t}$ is the probability of animal j receiving a light discount on day t, D is a standard normal cumulative density function, 525 is the critical carcass weight for the light carcass discount, $SW_{j,t}$ is the simulated slaughter weight of animal j on day t, σ_{we} is the standard deviation of the differences between the actual and simulated slaughter weights (i.e. weight error) of the 467 animals in the data set, $PH_{j,t}$ is the probability of animal j receiving a heavy discount on day t, and 950 is the critical carcass weight for the heavy weight discount.

However, this study assigned weight discounts based on simulated weight. This method sets $PL_{j,t}$ equal to 1 if the animal's simulated carcass weight was less than 525 pounds or zero otherwise. Likewise, $PH_{j,t}$ was set equal to 1 if the animal's simulated carcass weight was greater than 950 pounds and zero otherwise.

When results from the growth simulator using the probabilities generated in Equation 22 were compared to the results from simply assigning discounts based on simulated weight, the optimal number of days on feed decreased 2 days and total profits declined about $1,000. Given this small difference in days on feed and profits, bias introduced appears to be small.

Table 4.1 Carcass Characteristics by Days on Feed for Cattle in Original Dataset

	Days on Feed			
Characteristic	117	131	145	159
Hot Carcass Weight (lb.)	755	807	541	887
Dressing Percent	62.3	63.4	63.6	64.9
Low Choice	39.47%	46.90%	53.41%	61.79%
High Choice	7.67%	7.85%	18.16%	18.34%
Ribeye Area (sq. in)	12.79	12.90	12.52	13.61
Average Yield Grade	2.78	3.17	3.59	3.70
Percent Yield Grade 1 and 2	61.55%	42.58%	22.07%	15.05%
Percent Yield Grade 4 and 5	.83%	2.63%	6.95%	17.49%

Table 4.2 Feeder Cattle Purchase Price Adjustment Factors

Purchase Weight (pounds)	Adjustment Factor
500-599	1.104
600-699	1.045
700-799	1.000
800-900	.9202
>900	.8886

Table 4.3 Base High Paying Grid and Low Paying Grid used in Analysis

Characteristic	Base Grid	Low Paying Grid
Quality Grade:		
Prime	10.00	3.00
Select	-6.50	-10.00
Standard	-15.00	-25.00
Yield Grade:		
1	6.50	1.00
2	2.50	1.00
4	-17.00	-18.00
5	-17.00	-25.00
Weight:		
400 – 500	-17.00	-25.00
500 – 550	-17.00	-15.00
950 – 1000	-17.00	-15.00
1000+	-17.00	-25.00

Table 4.4 Profit and Carcass Characteristics Reported by Placement Weight when Animals are not Sorted

Purchase Price ($/cwt) =	86.90
Cost of Feed ($/ton) =	125.00
Dry Matter =	100%
Base Grid Price ($/cwt) =	113.50

Pen	Number of Animals	Days on Feed	Average Price	Total Revenue	Total Costs	Total Profit	Profit Per Head
6	25	131	$111.11	$20,244.69	$20,235.80	$8.89	$0.36
7	241	131	$110.20	$212,342.19	$212,352.41	($10.22)	($0.04)
8	179	131	$109.33	$166,270.01	$161,704.95	$4,565.06	$25.50
9	22	131	$108.40	$21,309.87	$20,855.04	$454.83	$20.67
Avg		131	$109.76	$420,166.76	$415,148.20	$5,018.56	$10.75

	Average Percent in Yield Grade				
Pen	1	2	3	4	5
6	10.21%	53.83%	31.78%	3.83%	0.35%
7	5.04%	40.41%	45.97%	7.84%	0.74%
8	3.09%	30.50%	53.08%	12.12%	1.21%
9	2.05%	22.96%	56.18%	17.00%	1.81%
Avg	5.10%	36.93%	46.75%	10.20%	1.03%

	Average Percent in Quality Grade			
Pen	Prime	Choice	Select	Standard
6	0.50%	49.88%	43.57%	6.06%
7	0.63%	55.73%	38.81%	4.82%
8	0.74%	59.46%	35.66%	4.14%
9	0.84%	62.45%	33.06%	3.65%
Avg	0.68%	56.88%	37.77%	4.67%

	Percent		Average
Pen	Light	Heavy	Weight
6	0.00%	0.00%	1,162
7	0.00%	0.00%	1,268
8	0.00%	0.00%	1,343
9	0.00%	0.00%	1,408
Avg			1,295

Table 4.5 Profit and Carcass Characteristics when Animals are Sorted into Pens Based on Placement Weight

Purchase Price ($/cwt) =	86.90
Cost of Feed ($/ton) =	125.00
Dry Matter =	100%
Base Grid Price ($/cwt) =	113.50

Pen	Number of Animals	Days on Feed	Average Price	Total Revenue	Total Costs	Total Profit	Profit Per Head
6	25	151	$109.92	$21,084.99	$20,935.36	$149.63	$5.99
7	241	136	$109.81	$214,244.43	$214,156.52	$87.91	$0.36
8	179	125	$109.86	$164,728.75	$160,057.95	$4,670.80	$26.09
9	22	116	$109.88	$20,893.65	$20,340.27	$553.38	$25.15
Avg		132	$109.87	$420,951.82	$415,490.10	$5,461.72	$11.70

	Average Percent in Yield Grade				
Pen	1	2	3	4	5
6	3.65%	34.04%	51.03%	10.28%	1.00%
7	3.80%	34.86%	50.46%	9.92%	0.96%
8	4.22%	37.05%	48.86%	9.01%	0.86%
9	4.59%	38.82%	47.48%	8.33%	0.79%
Avg	4.07%	36.19%	49.46%	9.38%	0.90%

	Average Percent in Quality Grade			
Pen	Prime	Choice	Select	Standard
6	0.79%	60.90%	34.42%	3.90%
7	0.71%	58.56%	36.43%	4.30%
8	0.64%	56.07%	38.54%	4.75%
9	0.59%	53.90%	40.34%	5.18%
Avg	0.68%	57.36%	37.43%	4.53%

Pen	Percent Light	Percent Heavy	Average Weight
6	0.00%	0.00%	1,220
7	0.00%	0.00%	1,283
8	0.00%	0.00%	1,325
9	0.00%	0.00%	1,365
Avg			1,298

Table 4.6 Profit and Carcass Characteristics for Animals Sold on an Individual Basis and Reported by Placement Weight

Purchase Price ($/cwt) =	86.90
Cost of Feed ($/ton) =	125.00
Dry Matter =	100%
Base Grid Price ($/cwt) =	113.50

Pen	Number of Animals	Days on Feed	Average Price	Total Revenue	Total Costs	Total Profit	Profit Per Head
6	25	151	$109.88	$21,109.08	$20,953.75	$155.33	$6.21
7	241	136	$109.81	$214,398.02	$214,247.29	$150.73	$0.63
8	179	125	$109.84	$164,854.32	$160,146.06	$4,708.26	$26.30
9	22	116	$109.90	$20,885.55	$20,330.57	$554.98	$25.23
Avg		132	$109.86	$421,246.97	$415,677.67	$5,569.30	$11.93

	Average Percent in Yield Grade				
Pen	1	2	3	4	5
6	3.56%	33.48%	51.39%	10.54%	1.03%
7	3.75%	34.58%	50.65%	10.04%	0.98%
8	4.15%	36.68%	49.13%	9.16%	0.88%
9	4.66%	39.16%	47.20%	8.20%	0.78%
Avg	4.03%	35.97%	49.59%	9.49%	0.92%

	Average Percent in Quality Grade			
Pen	Prime	Choice	Select	Standard
6	0.80%	61.16%	34.18%	3.86%
7	0.72%	58.70%	36.31%	4.27%
8	0.65%	56.26%	38.38%	4.72%
9	0.58%	53.72%	40.49%	5.21%
Avg	0.68%	57.46%	37.34%	4.52%

	Percent		Average
Pen	Light	Heavy	Weight
6	0.00%	0.00%	1,222
7	0.00%	0.00%	1,284
8	0.00%	0.00%	1,326
9	0.00%	0.00%	1,364
Avg			1,299

Table 4.7 Per Head Profits and Carcass Characteristics for the Three Sorting Systems under the Base High Paying Grid and a Low Paying Grid

System - Grid	Profit per Head	Percent YG4	Percent Choice	Average Weight
All - Base	$10.75	9.70%	57.16%	1,298
All - Low	($10.82)	13.33%	60.94%	1,318
Pen - Base	$11.70	9.38%	57.36%	1,298
Pen – Low	($9.76)	11.88%	60.03%	1,313
Individual - Base	$11.93	9.65%	57.66%	1,301
Individual - Low	($9.33)	13.20%	61.31%	1,321

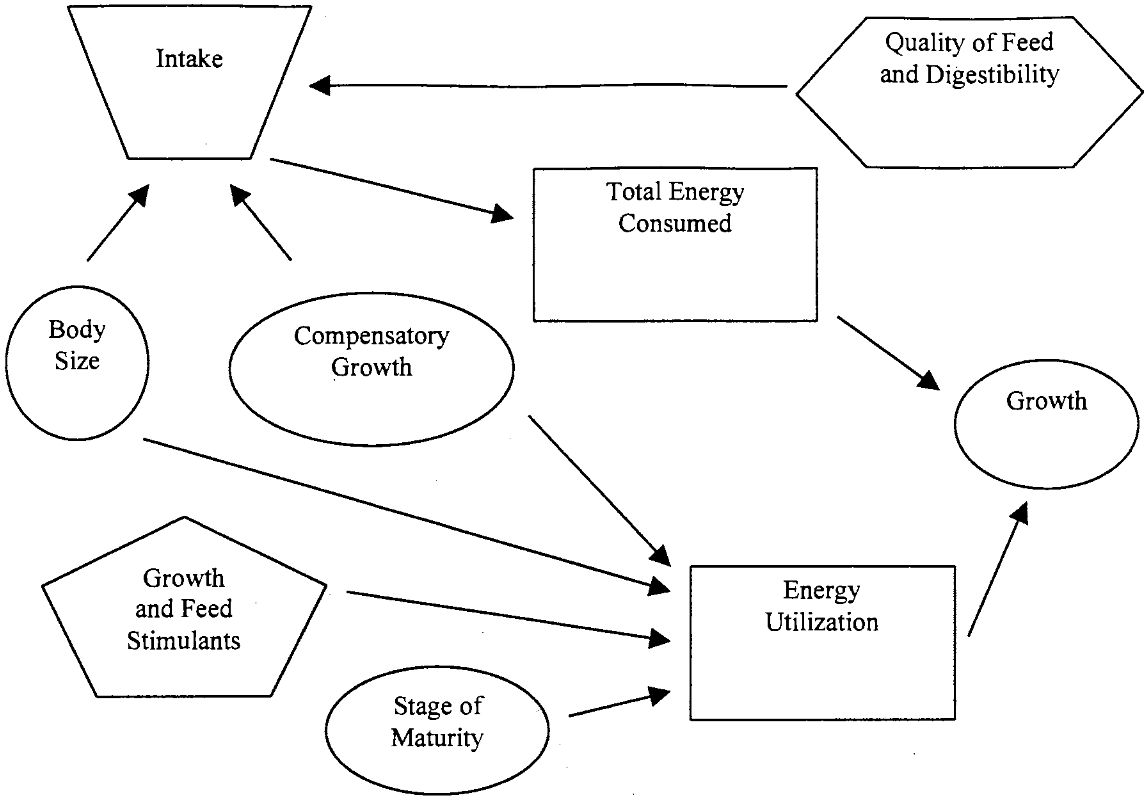

Figure 4.1 Factors affecting Cattle Growth

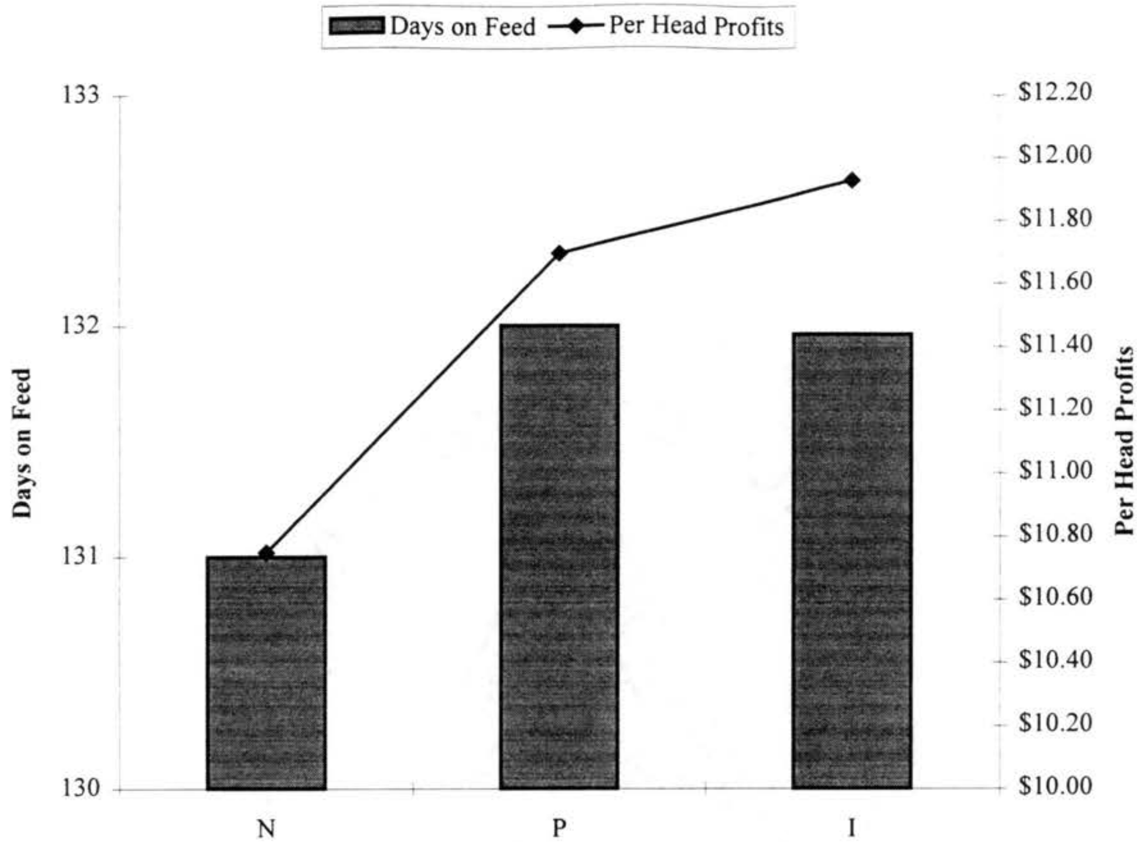

Figure 4.2 Days on Fed and Per Head Profits for the 3 Sorting Systems

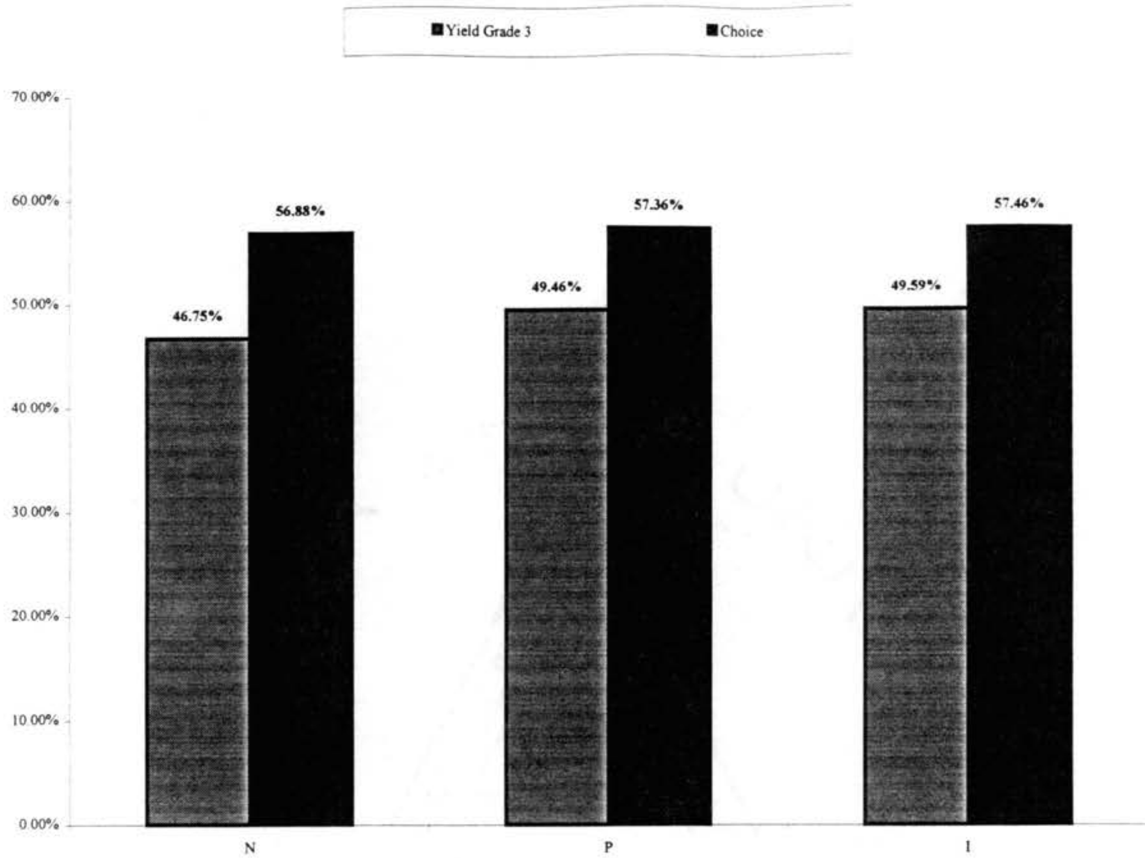

Figure 4.3 Average Percentage of Cattle achieving a Yield Grade 3 or a Choice Quality Grade for the 3 Sorting Systems

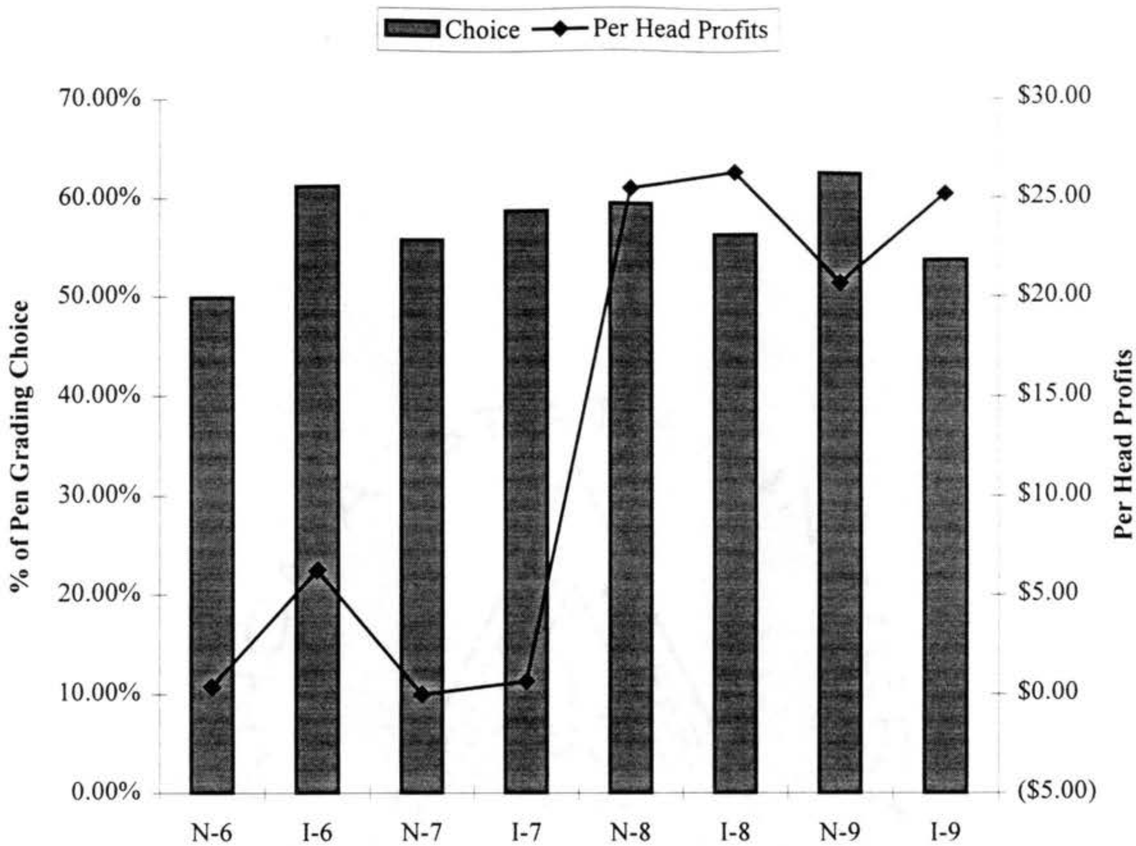

Figure 4.4 Percentage of Animals grading Choice and Per Head Profits for the Non-Sorting and Individual Sorting Systems at the Pen Level

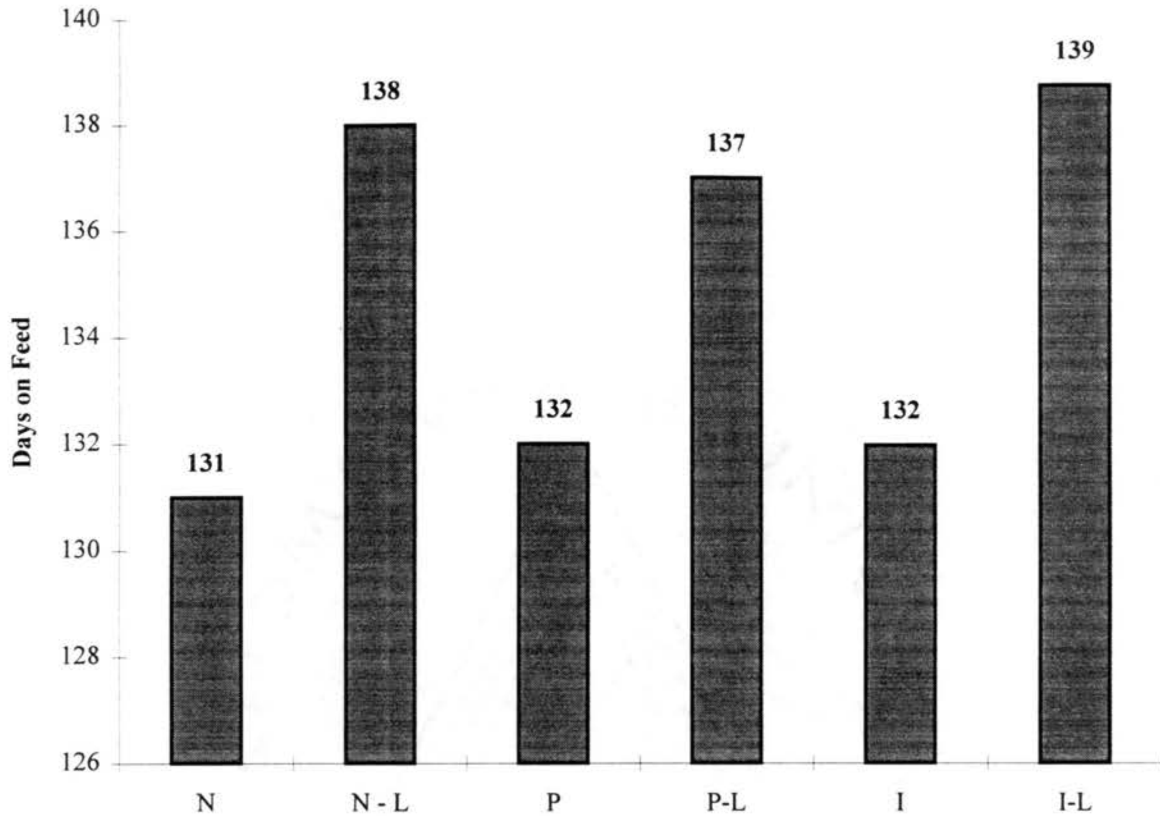

Figure 4.5 Days on Feed under High paying and Low Paying Grids in the 3 Sorting Systems

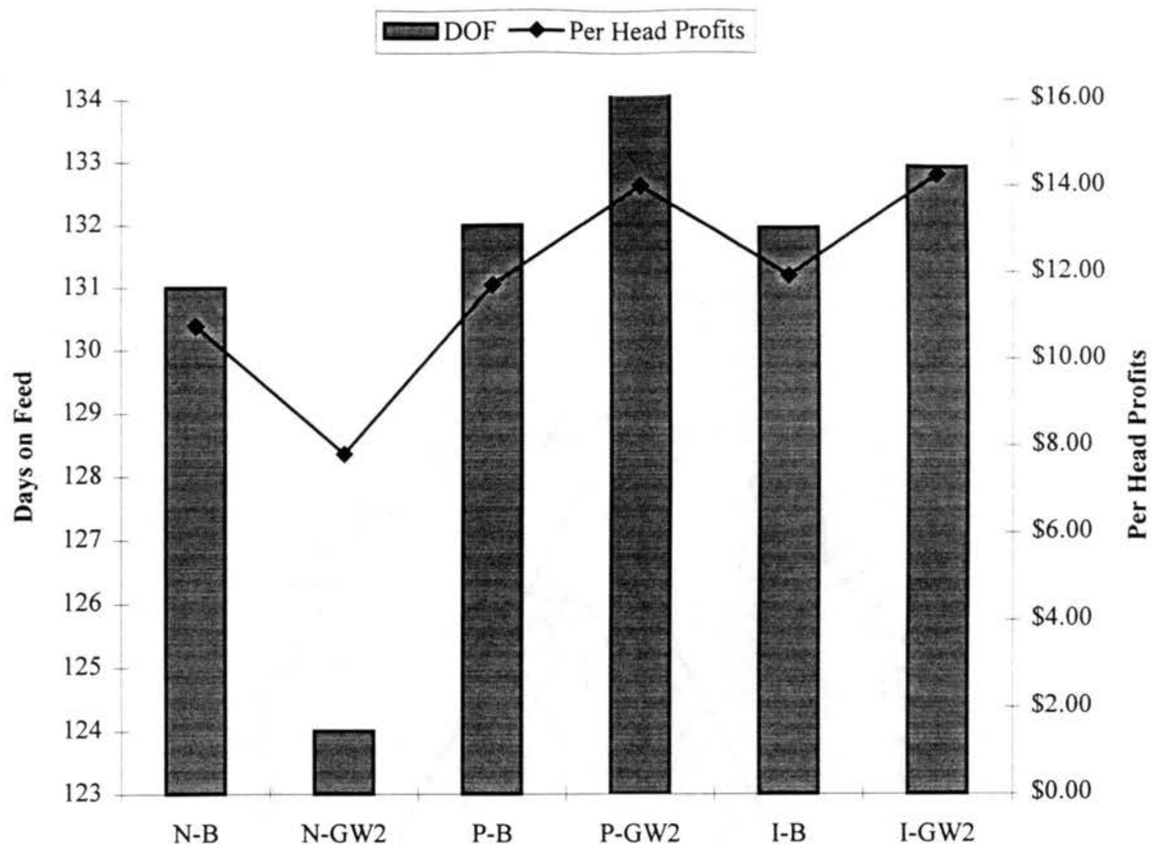

Figure 4.6 Days on Feed and Per Head Profits for the 3 Sorting Systems given Different Degrees of Heterogeneity

Chapter V

Concluding Remarks

The preceding chapters looked at three issues concerning value based pricing in the cattle industry. These articles addressed price discovery and management issues in the United States cattle feeding sector. The following will summarize the main findings in each article.

Effects of Specific Carcass Characteristics on the Volatility of Animal Value

The first article, "The Impact of Grid Pricing Premiums and Discounts on Individual Animal Values", found that 34 percent of the variation in animal value under grid pricing is the result of price premiums and discounts for quality characteristics. Specifically, quality grade, yield grade and light and heavy carcass discounts explain 10 percent, 14 percent, and 10 percent of the variability in total animal values. Weight, which accounts for all of the variation of live and dressed carcass weight pricing, accounts for the remaining 66% of the variation in the value of animals sold on a grid. Therefore, weight rather than quality characteristics still dominates cattle producer's decisions about how to produce cattle and when to sell them on the grid. However, it is important to note that for the base grid used in this research yield grade may be a slightly more important quality factor in explaining variation in animal value.

Grid pricing was used to value 1,278 head of cattle for which carcass data were available. If the cattle in this sample are divided into quartiles based on each animal's grid value, the difference in grid value between the average animals in the top quartile versus the bottom quartile is $207.38. As $135 (liveweight) to $150 (dressed weight) of the grid value difference can be apportioned to weight, the remaining $57 to $72 of the grid value difference between the two quartiles can be attributed to quality differences.

Implications

No estimates have been made here of how much it costs to change the quality of cattle in the lower quartile of cattle so they have carcass characteristics similar to cattle in the upper quartile, nor is an estimate of this type known to exist. Therefore, it is not clear whether $57 or $72 premiums from selling on the grid are large enough to provide incentives to adjust feedlot production practices and cow/calf genetic selection decisions. To determine whether these premiums are large enough to encourage cattle quality improvements, several things need to be considered. While these quality premiums are 3-5 times more than "average" cattle feeding profits, one has to determine whether increases in feeding costs will exceed this 10 percent gain in revenues. Additionally, one must establish if a potential gain of $135 to $150 from increasing the weight of cattle in the lower quartile can be achieved without adversely affecting quality.

Future Improvements

After this article was written, several new grids were being offered. These 'new era' grids have substantially higher premiums and smaller discounts. The coefficient of separate determination procedure in this article should re-run using these "new era" grids to determine if the recent grid changes have affected the amount of variation in animal value explain by quality characteristics, which will result in more accurate economic signals being transmitted from consumer to producer regarding quality characteristics.

Effects of Alternative Grid Structures

The second article, "Impact of Alternative Grid Pricing Structures on Cattle Marketing Decisions", uses a growth simulation model, logistic regression, and an optimization routine in Excel to maximize expected profits and determine the effect of different pricing structures on the number of days on feed.

Several pricing methods and grid structures were used: (A) constant baseline, (B) a base grid with high Prime premiums and Yield Grade 3/4 and 3/5 discounts, (C) grids with large and small discounts for Select and Standard carcasses, and (D) grids with large and small discounts associated with Yield Grade 4 and 5 carcasses. The important effects of the pricing structures on fed cattle marketing decisions are:

- The structure of the grid, primarily the relationship between quality grade discounts and yield grade discounts, affects the number of days on feed. More specifically, large quality grade discounts and small yield grade discounts increases the number of days on feed. While small quality grade discounts and large yield grade discounts result in fewer days on feed.
- A $1 increase in the Choice/Select spread, all else constant, will cause the number of days on feed to increase about 1.1 days.
- A $1 increase in the Yield Grade 3/4 spread, all else constant, will cause days on feed to decrease by 1.5 days.

(1) There is a negative relationship between the number of days on feed and feed price. For every $1 per ton increase in feed price, days on feed will decline .09 days, all else constant.

Implications

Grid pricing not only brings complexity into the marketing system but it also improves pricing accuracy. As price and profit are important signals to feedlot owners to change marketing decisions, viable marketing decisions will depend on whether price incentives are present. This research indicates that adjusting days on feed is a viable marketing decision for feedlot owners. Some believe that cattle that will be sold on a grid need to be fed longer to increase the likelihood of earning Prime premiums. However, this research suggests that the length of time on feed differs depending on the grid being considered. To increase profits and achieve gains in efficiency, it appears that cattle need to be fed and targeted at specific grids. This, however, requires knowledge of each animal's growth capability and careful monitoring of carcass characteristics over the feeding period.

Future Improvements

This research is by no means exhaustive. The results are based on one pen of experimental data. Further research needs to look at the effects of breed, frame size, and environmental conditions on marketing decisions. Additionally, adjustments can be made to the energy content of the diet, the base grid price, and the purchase price of feeder cattle to see how these changes impact profitability and days on feed. Also, it may be necessary to account for imperfect knowledge/risk in predicting grades, cost of gain, etc.

Returns to Sorting in a Grid Pricing System

The third article, "Effects of Sorting and Heterogeneity on Cattle Marketing Decisions ", indicates that homogeneous cattle sorted by placement weight into 100 pound weight categories (i.e. sorting into pens) resulted in a $.95 increase in per head profits. Sorting on an individual basis so that each animal is sold at an optimum point resulted in an increase in per head profits of $1.18. The benefits of sorting depend on the placement weight of animals. Those animals on the extremes of the weight distribution benefit the most from sorting. By individually sorting these 'outlier' cattle, feeders can achieve gains in per head profits of $4.55 (heavy placement weights) to $5.86 (light placement weights). The grid animals are sold under has an impact on the returns to sorting. When cattle are sold under a low paying grid, sorting premiums increased to $1.05 and $1.48 in the pen and individual sorting systems, respectively. The degree of heterogeneity has the greatest impact on sorting premiums. When more heterogeneous cattle are fed and sold under the base grid, sorting premiums increase to over $6.24 per head in a pen sorting system and $6.49 per head in an individual sorting system.

Other research suggests that more scientific methods of sorting after placement achieve higher returns to sorting – from $11 to $25 per head. The findings from this research indicate that sorting relatively homogeneous cattle at placement adds very little to profits. However, given a level of heterogeneity similar to industry conditions, returns to sorting of more than $6 per head were estimated for this simplistic placement weight sorting method. On a relative scale, the simplistic sorting method premiums of more than $6 per head appear to be consistent with the ultrasound premium findings.

Implications

This research suggests that sorting by placement weight does result in higher profits when cattle are sold in a value based marketing system. However, this research does not take directly account for the additional costs of labor and the performance effect of commingling cattle. The true cost of sorting is difficult to estimate but some feeders who sort cattle using ultrasound technology estimate that the cost of sorting ranges between $4 and $5 a head. Sorting cattle at placement into 100 pound weight categories should be less costly than ultrasound. Additionally, a simple sorting method based on placement weight avoids any economic and biological losses in performance that are associated with sorting and commingling cattle after a significant time on feed. Therefore, sorting heterogenous cattle at placement is a viable approach to marketing cattle at an optimal point.

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Appendix A

Animal Growth and Cost of Gain Model Equations

The biological growth model used summarizes and applies factors known to influence body composition and feedstuff utilization. It is based on the net energy system developed by G.P. Lofgreen and W.N. Garrett in 1963 and later modified by D.G. Fox and J.R. Black and the National Research Council (NRC). The three primary relationships that drive this model are: (A) net energy requirement for maintenance of body weight, (B) dry matter intake, and (C) daily gain. Key parameters of the dry matter intake and daily gain equations were calibrated to minimize prediction errors in slaughter weight for each of the 467 steers in the original dataset. The parameter calibration used Excel's "Solver" routine in conjunction with an Excel spreadsheet version of the growth simulator. Given accurate estimates of daily intake and gain, the growth model can be used to estimate daily cost after specifying feed cost per pound, an interest rate, and other typical custom feeding "yardage" charges for feeding services.

The first step needed to model animal growth is to determine the average weight of the animal and the net energy required for maintenance on a specific day:

(1) $$MFW_t = BW_{t-1} + (DG_{t-1} \; / \; 2)$$

(2) $$NEM_t = .077 \; MFW_t^{.75}$$

where t is the current day on feed, MFW_t is the mean feeding weight in kilograms on day t, BW_{t-1} is the liveweight in kilograms at the end of day $t-1$, and DG_{t-1} is the daily gain in kilograms on the previous day. DG_{t-1} is assumed to be 1.36 kilograms on day 1 and the calculated value from Equation 5 converted to kilograms thereafter. BW_{t-1} is assumed to be placement weight of the animal on day 1 and the calculated value from Equation 6 converted to kilograms thereafter. NEM_t is the net energy for maintenance in Mcal per day on day t.

The second step in calculating animal growth is to determine the dry matter intake of the animal on a specific day. The original function to calculate daily intake was developed by Donald R. Gill in 1979. Given the changes in cattle over time (frame size, efficiency, etc.), two of the intake parameters were calibrated so the sum of the squared differences between the actual average intake of an animal and the predicted intake of the animal on the day of slaughter is minimized. Using the new calibrated parameters, the daily dry matter intake on a specific day is:

(3) $$\text{DMI}_t = .375 * \begin{pmatrix} .1801 + .01 * IF + PW \; / \; 4545 * (BW_{t-1} \wedge .75) \\ - (.01 * BW_{t-1} - 2.5) \wedge 2 \end{pmatrix}$$

where DMI_t is dry matter intake in kilograms on day t, .375 and the second .01 are the calibrated intake parameters, IF is the appropriate intake factor based on placement weight that appears in Table A.1, PW is the placement weight of the animal in kilograms, and BW_{t-1} is the liveweight of the animal in kilograms on day $t-1$. BW_{t-1} is assumed to be placement weight of the animal on day 1 and the calculated value from Equation 6 converted to kilograms thereafter.

Table A.1 Intake Factors for Dry Matter Intake Function

Placement Weight		
Kilograms	Pounds	Intake Factor
<280	<617.4	4.2
280-299	617.4-661.4	4.5
300-319	661.5-705.5	4.8
320-340	705.6-749.7	5.5
>340	>749.7	6.0

After calculating dry matter intake and net energy for maintenance, the daily gain of each animal can be calculated. The intercept parameter on the daily gain function was calibrated so the sum of the squared differences between the actual slaughter weight and the predicted weight at slaughter is minimized. The calculations of feed for maintenance, net energy for gain, and daily gain are:

(4)
$$FFM_t = NEM_t / NEMA$$
$$NEFG_t = (DMI_t - FFM_t) * NEGA$$

(5)
$$DG_t = 60.8132 * MFWlb_t^{-.6837} * NEFG_t^{.9116}$$

where FFM_t is feed required for maintenance in kilograms on day t, NEM_t is net energy for maintenance in Mcal on day t from Equation 2, $NEMA$ is the net energy value of the ration available for maintenance in Mcal per kilogram of dry matter, $NEFG_t$ is the net energy available for gain in Mcal per day, $NEGA$ is the net energy value of the ration for available for gain in Mcal per kilogram of dry matter, DG_t is daily gain in pounds for day t, and $MFWlb_t$ is the mean feeding weight for day t from Equation 1 converted to pounds.

Using the daily gain value calculated in Equation 5, the calculations of current weight on day t, dressing percentage, and hot carcass weight are:

(6)
$$BW_t = (BW_{t-1} + DG_t)$$

(7)
$$DrsPcnt_t = (59.244357 + .0029927\ BW_t) / 100$$

(8)
$$HCW_t = BW_t * DrsPcnt_t$$

where BW_t is the liveweight in pounds on day t, BW_{t-1} is the liveweight from the end of the previous day in pounds, DG_t is the daily gain in pounds on day t from Equation 5, $DrsPcnt_t$ is the carcass dressing percent on day t, and HCW_t is the hot carcass weight in pounds on day t.

The cost of feed for the current day on feed is:

(9)
$$FdC_t = DMIlb_t * ((P_F / PDM) / 2000)$$

where FdC_t is the feed cost in dollars on day t, $DMIlb_t$ is the dry matter intake on day t from Equation 3 converted to pounds, P_F is the cost of feed in \$ per ton, and PDM is percentage of dry matter in the feed.

Other costs include:

(10)
$$PC = (PW/100) * FdrC * PPAF$$

(11)
$$I_t = (.75 * (PC + Fr)) * IR * (t / 360)$$

(12) $$OpC_t = \left(.75 * \left(VM + CO + Other + (Y * t) + \sum_{t=1}^{T} FdC_t \right) \right) * IR * (t / 720)$$

(13) $$DL = (PC + VM) * PDL$$

(14) $$MiscC_t = Fr + VM + CO + Other + (Y * t)$$

where *PC* is the purchase cost of the feeder animal in dollars, *PW* is the placement weight of the animal on day 1 in pounds, *FdrC* is the average cost of a 700 to 800 pound animal in dollars per hundredweight, PPAF is the purchase price adjustment factor for a given placement weight that appears in Table A.2, I_t is the interest cost in dollars for *t* days on feed, *Fr* is the cost of freight in dollars per head, *IR* is the annual interest rate, OpC_t is the cumulative operating costs, *VM* is the veterinary/medical costs of treating a sick animal in dollars per head, *CO* is the $1 per head check off that is collected on each animal sold, *Other* are any miscellaneous costs in $ per head, *Y* is the yardage cost for *t* days on feed, $\sum_{t=1}^{t} FdC_t$ is the cumulative cost of feed in dollars using Equation 9, *DL* is the cost of death loss in dollars her head, *PDL* is the percentage death loss, and $MiscC_t$ is the miscellaneous costs of feeding cattle in dollars per head on day *t*.

Table A.2 Feeder Cattle Purchase Price Adjustment Factors

Placement Weight (pounds)	Adjustment Factor
500-599	1.104
600-699	1.045
700-799	1.000
800-900	.9202
>900	.8886

The final step is to determine the total cost of feeding an animal from day 1 to day *t*. Total cost per head on day t is:

(15) $$TC_t = PC + I_t + OpC_t + DL + MiscC_t + \sum_{t=1}^{t} FdC_t$$

where PC, I_t, OpC_t, DL, $MiscC_t$ and FdC_t are calculated in Equations 10, 11, 12, 13, 14, and 9, respectively.

Logistic Regression for Yield and Quality Grade Prediction

To calculate the grid value of each animal and evaluate the impact of alternative grids, it is necessary to determine the probability of a particular animal achieving each yield and quality grade after every day on feed. Two logit models will be estimated in SAS™ for this purpose. The basic functional forms of these logistic regression equations are:

(16)
$$Yield\ Grade = f\left[Log(Slaughter\ Weight), Log\left(Days\ on\ Feed^2\right)\right]$$
$$Quality\ Grade = g\left[Log(Slaughter\ Weight), Log\left(Days\ on\ Feed^2\right)\right]$$

The estimated logistic intercept and slope parameters and their associated Chi-Square values and p-values appear in Table A.3. Each of the estimated parameters is significant at the 5% level. A goodness of fit criterion for each model appears in Table A.4. The –2 Log L criterion p-value indicates in each logistic regression the variables are jointly significant at the 5% level. Therefore, both the yield and quality grade logistic regression models are appropriate.

Table A.3 Intercept and Slope Parameters for the Yield and Quality Grade Logistic Regression Equations

Variable	Yield Grade			Quality Grade		
	Parameter Estimate	Wald Chi-Square[a]	P-Value	Parameter Estimate	Wald Chi-Square[a]	P-Value
Int_1	82.0939	93.24	.0001	-35.9428	18.97	.0001
Int_2	84.8634	98.53	.0001	-30.6281	13.93	.0002
Int_3	87.4282	103.03	.0001	-27.9	11.60	.0007
Int_4	89.9601	108.39	.0001	---	---	---
Log(Slaughter Weight)	-8.7489	44.76	.0001	2.7558	4.30	.04
Log(Days on Feed^2)	-2.3111	24.11	.0001	1.148	5.54	.02

a: Under the null hypothesis that the coefficient is zero, the statistic has a χ^2 distribution.

Table A.4 -2 Log L Goodness of Fit Criterions for the Yield and Quality Grade Logistic Regression Equations

Goodness of Fit Criterion	Yield Grade			Quality Grade		
	Chi-Square	df	P-Value	Chi-Square	df	P-Value
-2 Log L	134.75	2	.0001	20.37	2	.0001

The functions used to assign each yield and quality grade probability to an animal, *j*, on a specific day, *t*, are:

$$GF_{i,j,t} = Int_i + BSW * LCW_{j,t} + BDOF * LSt \qquad for\ j = 1\ to\ 467$$

(17)

$$P_{i,j,t} = \frac{e^{GF_{i,j,t}}}{1+e^{GF_{i,j,t}}} \qquad if\ i = 1$$

$$P_{i,j,t} = \frac{e^{GF_{i,j,t}}}{1+e^{GF_{i,j,t}}} - \frac{e^{GF_{i-1,j,t}}}{1+e^{GF_{i-1,j,t}}} \qquad if\ i = 2\ to\ k-1$$

$$P_{i,j,t} = 1 - \frac{e^{GF_{i-1,j,t}}}{1+e^{GF_{i-1,j,t}}} \qquad if\ i = k$$

where i is a particular yield grade (i.e. i=1, 2, 3, 4) or quality grade (i.e. i=1, 2, 3), $GF_{i,j,t}$ is a grading function, Int_i is the logistic intercept parameter estimate generated in SAS™, BSW is the yield grade or quality grade logistic slope estimate for the slaughter weight variable estimated in SAS™, $BDOF$ is the yield grade or quality grade logistic slope estimate for the days on feed variable estimated in SAS™, $LCW_{j,t}$ is the logged current weight of animal j on day t, LSt is the current day on feed, t, that is squared and then logged, e=2.718282, and $P_{i,j,t}$ is the probability of animal j achieving a specific yield or quality grade, i, on day t. In this analysis, k is the maximum number of yield or quality grades so k=5 for yield grades and k=4 for quality grades.

After t days on feed, the total cost of feeding and the components needed to calculate an animal's grid value are known so its profit can be determined. The expected profit for an individual animal, j, on day t can be written mathematically as:

(18) $$E(\pi_{j,t}) = \left(BGP + \sum_{x=1}^{5} (PYG_{x,j,t} * YG_x) + \sum_{y=1}^{4} (PQG_{y,j,t} * QG_y) - (PL_{j,t} * L) - (PH_{j,t} * H) - TC_{j,t} \right) * (BW_{j,t} * DrsPcnt_{j,t})$$

where $E(\pi_{j,t})$ is the expected profit for animal j on day t, BGP is the base grid price for a Choice, Yield Grade 3 carcass, $PYG_{x,j,t}$ is animal j's probability of attaining Yield Grade x on day t from Equation 17, YG_x is the \$/hundredweight premium/discount for Yield Grade x, $PQG_{y,j,t}$ is animal j's probability of achieving a Quality Grade y on day t from Equation 17, QG_y is the \$/hundredweight premium/discount for Quality Grade y, $PL_{j,t}$ equals 1 (receives a light carcass discount on day t) if the hot carcass weight from Equation 8 is less than 525 pounds and zero otherwise[1], L is the light carcass discount applied to a carcass weighing under 5.25 hundredweight, $PH_{j,t}$ equals 1 (receives a heavy carcass discount on day t) if the hot carcass weight from Equation 8 is greater than 950 pounds and zero otherwise[1], $TC_{j,t}$ is animal j's total cost of feeding as of day t calculated in Equation 15, $BW_{j,t}$ is animal j's liveweight on day t from Equation 6, and $DrsPcnt_{j,t}$ is animal j's dressing percentage on day t from Equation 7.

Maximum expected profits, based on Equation 18, are used to identify the optimal number of days on feed and the returns to sorting. In Chapters III and IV, the mathematical expression to identify the maximum expected profit when all 467 animals are sold on the same day, t, is:

(19) $$\underset{t}{Max} \sum_{j=1}^{467} E(\pi_{j,t})$$

where $E(\pi_{j,t})$ is the expected profit generated by the j th animal on day t.

When cattle are sorted into pens based on placement weight in Chapter IV, the maximum expected profit equation used for each of the p pens is:

(20) $$\underset{t}{Max} \sum_{j=1}^{J} E(\pi_{j,t})$$

where $E(\pi_{j,t})$ is the expected profit for the j th animal on day t, and J is the total number of animals in a particular pen.

In Chapter IV, cattle are also sold on an individual basis so the maximum expected profit equation becomes:

(21) $$\underset{t}{Max}\, E(\pi_{j,t})$$

where $E(\pi_{j,t})$ is the expected profit generated by the j th animal on day t.

Endnotes

1: Mathematically, E(f(x))=f(E(x)) only if the function f is linear. In this research, the weight discount function is nonlinear so some bias could be introduced by assuming that the expected discount for weight is equal to the discount for expected weight – E(Discount(weight)) = Discount(E(weight)). The extent of the possible bias was investigated.

Weight discount probabilities were derived using a standard normal cumulative density function and the expected weight of the animal. In Excel, skewness and kurtosis tests on the weight error (actual weight at slaughter – simulated weight at slaughter) distribution validated the assumption of normality. The estimated standard deviation of the 467 weight errors, σ_{we}, was 65.18. The calculations used to determine the probability of animal j receiving a light or heavy discount on day t are:

(22)

$$PL_{j,t} = D\left(\frac{525 - SW_{j,t}}{\sigma_{we}}\right)$$

$$PH_{j,t} = 1 - D\left(\frac{950 - SW_{j,t}}{\sigma_{we}}\right)$$

where $PL_{j,t}$ is the probability of animal j receiving a light discount on day t, D is a standard normal cumulative density function, 525 is the critical carcass weight for the light carcass discount, $SW_{j,t}$ is the simulated slaughter weight of animal j on day t, σ_{we} is the standard deviation of the differences between the actual and simulated slaughter weights (i.e. weight error) of the 467 animals in the data set, $PH_{j,t}$ is the probability of animal j receiving a heavy discount on day t, and 950 is the critical carcass weight for the heavy weight discount.

However, this study assigned weight discounts based on simulated weight. This method sets $PL_{j,t}$ equal to 1 if the animal's simulated carcass weight was less than 525 pounds or zero otherwise. Likewise, $PH_{j,t}$ was set equal to 1 if the animal's simulated carcass weight was greater than 950 pounds and zero otherwise.

When results from the growth simulator using the probabilities generated in Equation 22 were compared to the results from simply assigning discounts based on simulated weight, the optimal number of days on feed decreased 2 days and total profits declined about $1,000. Given this small difference in days on feed and profits, bias introduced appears to be small.

Appendix B

Visual Basic Program for the All Animal Growth Model

The following is the Visual Basic code used to grow cattle and sells all the animals when profits are maximized.

```
Sub All()
Worksheets("growth").Activate
 Range("b19:ad1000").ClearContents
Worksheets("revenue").Range("g3:ag1000").ClearContents
Worksheets("All grid").Range("d4:d8").ClearContents
Worksheets("All grid").Range("a12:f12").ClearContents
Worksheets("All grid").Range("a17:e17").ClearContents
Worksheets("All grid").Range("a22:d22").ClearContents
Worksheets("All grid").Range("a27:c27").ClearContents
Worksheets("All cash").Range("d4:d8").ClearContents
Worksheets("All cash").Range("a12:e12").ClearContents
Worksheets("All cash").Range("a17:e17").ClearContents
Worksheets("All cash").Range("a22:d22").ClearContents
Worksheets("All cash").Range("a27:c27").ClearContents
Worksheets("All dressed").Range("d4:d8").ClearContents
Worksheets("All dressed").Range("a12:e12").ClearContents
Worksheets("All dressed").Range("a17:e17").ClearContents
Worksheets("All dressed").Range("a22:d22").ClearContents
Worksheets("All dressed").Range("a27:c27").ClearContents
Worksheets("All info").Range("a3:i210").ClearContents

Calculate

Dim days As Integer
 days = InputBox("On what DOF do you want to start recording?                    1 to Max Days on Feed", Recording,
115)
dof = Range("d13")
frmsize = Range("c5")
grwthint = Range("c8")

cnt = 0
 Do Until Cells(19 + cnt, 1) = Empty
  If Range("n9") = 2 Then
   Cells(19 + cnt, 20) = Rnd
   Cells(19 + cnt, 21) = Rnd
  End If
  cnt = cnt + 1
 Loop

For i = 1 To dof

' previous revenue used to calculate marginal grid revenue
prev = WorksheetFunction.Sum(Range("d19:d1000"))
' previous costs used to calculate marginal costs
pcost = WorksheetFunction.Sum(Range("f19:f1000"))
' previous weight used to calculate marginal revenue/costs
ptwght = WorksheetFunction.Sum(Range("c19:c1000"))

 k = 0
  Do Until Cells(19 + k, 1) = Empty
   Range("d14") = i
   Range("d15") = k + 1
```

```
' calculations for specified number of days on feed
If i = 1 Then
 ' body weight (kg)
 bw = Cells(19 + k, 1) / 2.205
 ' mean feeding weight (kg) - assumes a 3 lb gain on 1st day - half of that is
 ' used in the analysis
 mfw = bw + (1.5 / 2.205)
ElseIf i > 1 Then
 ' body weight (kg) is the growth model estimate
 bw = Cells(19 + k, 3) / 2.205
 ' mean feeding weight (kg) - half of the current daily gain
 mfw = bw + ((Cells(19 + k, 18) / 2) / 2.205)
End If

 ' net energy for maintanence requirement [NRC; modification of Fox & Black]
 nem = 0.077 * (mfw ^ 0.75)
 ' DM intake (kg) [intake function used in BeefGain program - considers yearlings only]
 stwt = Cells(19 + k, 1)
  intfac = Application.WorksheetFunction.HLookup(stwt, Range("k6:o7"), 2)
  factor = Range("c7") + (Range("d7") * intfac) + (Cells(19 + k, 1) / 2.205) / 4545
  intake = Range("c6") * (factor * (bw ^ 0.75) - (Range("d6") * bw - 2.5) ^ 2)

 If Range("c10") = 1 Or Range("c10") = 3 Then
  intake = intake * (1 + Cells(19 + k, 28))
 End If

 intakelb = intake * 2.205

 ' daily gain (lb) [NRC with supplemental info from Fox & Black and An Sci FLCALC]
 ffm = nem / Range("d1")
  nefg = (intake - ffm) * Range("d2")
  mfwlb = mfw * 2.205
'    If frmsize = 1 Then
    'original intercept=65.571
    Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'     ElseIf frmsize = 2 Then
'     'original intercept=58.731
'      Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'      ElseIf frmsize = 3 Then
'      'original intercept=52.571
'       Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'       ElseIf frmsize = 4 Then
'       'original intercept=45.656
'        Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'        ElseIf frmsize = 5 Then
'        'original intercept=40.982
'         Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'         ElseIf frmsize = 6 Then
'         'original intercept=52.571
'          Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)

 If Range("c10") = 2 Or Range("c10") = 3 Then
  Cells(19 + k, 18) = Cells(19 + k, 18) * (1 + Cells(19 + k, 29))
 End If

' previous weight used for feed conversion calculation
pwght = Cells(19 + k, 3)

' current weight
If i = 1 Then
 Cells(19 + k, 3) = Cells(19 + k, 1) + Cells(19 + k, 18)
  ElseIf i > 1 Then
   Cells(19 + k, 3) = Cells(19 + k, 3) + Cells(19 + k, 18)
End If

' feed conversion
If i = 1 Then
 Cells(19 + k, 19) = intakelb / (Cells(19 + k, 3) - Cells(19 + k, 1))
  Else: Cells(19 + k, 19) = intakelb / (Cells(19 + k, 3) - pwght)
End If
```

```
' feed cost for current DOF
 cfc = intakelb * Range("j3")

 ' accumulated feed costs
 If i = 1 Then
  Cells(19 + k, 5) = cfc
   Else: Cells(19 + k, 5) = Cells(19 + k, 5) + cfc
 End If

If Cells(19 + k, 1) >= 700 And Cells(19 + k, 1) < 800 Then
 pp = Range("i1")
  ElseIf Cells(19 + k, 1) >= 400 And Cells(19 + k, 1) < 600 Then
   pp = Range("i1") * 1.104
    ElseIf Cells(19 + k, 1) >= 600 And Cells(19 + k, 1) < 700 Then
     pp = Range("i1") * 1.045
      ElseIf Cells(19 + k, 1) >= 800 And Cells(19 + k, 1) < 900 Then
       pp = Range("i1") * 0.9202
        ElseIf Cells(19 + k, 1) >= 900 Then
         pp = Range("i1") * 0.8886
End If

 purchcosts = ((Cells(19 + k, 1) / 100) * pp)
 cattleint = (0.75 * (purchcosts + Range("i8"))) * Range("i7") * (i / 360)
 deathloss = (purchcosts + Range("i10")) * Range("i9")
 othercosts = Range("i8") + Range("i10") + Range("i11") + Range("i12") + _
  (Range("i13") * i)
 operatingint = (0.75 * (Range("i10") + Range("i11") + Range("i12") + (Range("i13") * i) + _
  Cells(19 + k, 5))) * Range("i7") * (i / 720)

 Cells(19 + k, 6) = purchcosts + cattleint + deathloss + othercosts + _
  operatingint + Cells(19 + k, 5)

Calculate

' calculates probabilities of yield and quality grades for 1998 cattle
 drspcnt = (59.244357 + (0.0029927 * Cells(19 + k, 3))) / 100

  iy1 = 82.0939
  iy2 = 84.8634
  iy3 = 87.4282
  iy4 = 89.9601
  ygv1 = -8.7489
  ygv2 = -2.3111
   var1 = Log(Cells(19 + k, 3))
   var2 = Log(i ^ 2)
 ufy1 = iy1 + (ygv1 * var1) + (ygv2 * var2)
 ufy2 = iy2 + (ygv1 * var1) + (ygv2 * var2)
 ufy3 = iy3 + (ygv1 * var1) + (ygv2 * var2)
 ufy4 = iy4 + (ygv1 * var1) + (ygv2 * var2)

 Cells(19 + k, 7) = Exp(ufy1) / (1 + Exp(ufy1))
 Cells(19 + k, 8) = (Exp(ufy2) / (1 + Exp(ufy2))) - _
  (Exp(ufy1) / (1 + Exp(ufy1)))
 Cells(19 + k, 9) = (Exp(ufy3) / (1 + Exp(ufy3))) - _
  (Exp(ufy2) / (1 + Exp(ufy2)))
 Cells(19 + k, 10) = (Exp(ufy4) / (1 + Exp(ufy4))) - _
  (Exp(ufy3) / (1 + Exp(ufy3)))
 Cells(19 + k, 11) = 1 - (Exp(ufy4) / (1 + Exp(ufy4)))

  iq1 = -35.9428
  iq2 = -30.6281
  iq3 = -27.9
  qgva = 2.7558
  qgvb = 1.148
   vara = Log(Cells(19 + k, 3))
   varb = Log(i ^ 2)
 ufq1 = iq1 + (qgva * vara) + (qgvb * varb)
 ufq2 = iq2 + (qgva * vara) + (qgvb * varb)
 ufq3 = iq3 + (qgva * vara) + (qgvb * varb)
```

```
 Cells(19 + k, 12) = Exp(ufq1) / (1 + Exp(ufq1))
 Cells(19 + k, 13) = (Exp(ufq2) / (1 + Exp(ufq2))) - _
  (Exp(ufq1) / (1 + Exp(ufq1)))
 Cells(19 + k, 14) = (Exp(ufq3) / (1 + Exp(ufq3))) - _
  (Exp(ufq2) / (1 + Exp(ufq2)))
 Cells(19 + k, 15) = 1 - (Exp(ufq3) / (1 + Exp(ufq3)))

py1 = Cells(19 + k, 7)
py2 = Cells(19 + k, 8)
py3 = Cells(19 + k, 9)
py4 = Cells(19 + k, 10)
py5 = Cells(19 + k, 11)

yg1 = 0
yg2 = 0
yg3 = 0
yg4 = 0
yg5 = 0

 If Cells(19 + k, 20) <= py1 Then
  yg1 = 1
  ElseIf Cells(19 + k, 20) > py1 And Cells(19 + k, 20) <= (py1 + py2) Then
   yg2 = 1
    ElseIf Cells(19 + k, 20) > (py1 + py2) And Cells(19 + k, 20) <= (py1 + py2 + py3) Then
     yg3 = 1
      ElseIf Cells(19 + k, 20) > (py1 + py2 + py3) And Cells(19 + k, 20) <= (py1 + py2 + py3 + py4) Then
       yg4 = 1
        ElseIf Cells(19 + k, 20) > (py1 + py2 + py3 + py4) Then
         yg5 = 1
 End If

pq1 = Cells(19 + k, 12)
pq2 = Cells(19 + k, 13)
pq3 = Cells(19 + k, 14)
pq4 = Cells(19 + k, 15)

qg1 = 0
qg2 = 0
qg3 = 0
qg4 = 0

 If Cells(19 + k, 21) <= pq4 Then
  qg4 = 1
  ElseIf Cells(19 + k, 21) > pq4 And Cells(19 + k, 21) <= (pq4 + pq3) Then
   qg3 = 1
    ElseIf Cells(19 + k, 21) > (pq4 + pq3) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2) Then
     qg2 = 1
      ElseIf Cells(19 + k, 21) > (pq4 + pq3 + pq2) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2 + pq1) Then
       qg1 = 1
 End If

prime = Worksheets("revenue").Range("d12")
selct = Worksheets("revenue").Range("d13")
stndrd = Worksheets("revenue").Range("d14")
yield1 = Worksheets("revenue").Range("d16")
yield2 = Worksheets("revenue").Range("d17")
yield4 = Worksheets("revenue").Range("d18")
yield5 = Worksheets("revenue").Range("d19")

' net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 22) = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5) + _
  (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd)
 ElseIf Range("n9") = 1 Then
```

```
 Cells(19 + k, 22) = (Cells(19 + k, 7) * yield1) + _
  (Cells(19 + k, 8) * yield2) + _
  (Cells(19 + k, 10) * yield4) + _
  (Cells(19 + k, 11) * yield5) + _
  (Cells(19 + k, 12) * prime) + _
  (Cells(19 + k, 14) * selct) + _
  (Cells(19 + k, 15) * stndrd)
End If

' yield net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 23) = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5)
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 23) = (Cells(19 + k, 7) * yield1) + _
   (Cells(19 + k, 8) * yield2) + _
   (Cells(19 + k, 10) * yield4) + _
   (Cells(19 + k, 11) * yield5)
End If

' quality net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 24) = (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd)
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 24) = (Cells(19 + k, 12) * prime) + _
   (Cells(19 + k, 14) * selct) + _
   (Cells(19 + k, 15) * stndrd)
End If

' dressed profits
Cells(19 + k, 25) = (Worksheets("revenue").Range("d24") * ((Cells(19 + k, 3) * drspcnt) / 100)) - _
  Cells(19 + k, 6)

' cash profits
Cells(19 + k, 27) = (Worksheets("revenue").Range("d25") * (Cells(19 + k, 3) / 100)) - Cells(19 + k, 6)

' calculates the expected grid price and profit
'  If (Cells(19 + k, 3) * drspcnt) < Worksheets("revenue").Range("a21") Then
'   light = Worksheets("revenue").Range("d21")
'   heavy = 0
'   ElseIf (Cells(19 + k, 3) * drspcnt) > Worksheets("revenue").Range("a22") Then
'    light = 0
'    heavy = Worksheets("revenue").Range("d22")
'     Else
'      light = 0
'      heavy = 0
'  End If
'
' If light < 0 Then
'  Cells(19 + k, 16) = 1
'   Else: Cells(19 + k, 16) = 0
' End If
'
' If heavy < 0 Then
'  Cells(19 + k, 17) = 1
'   Else: Cells(19 + k, 17) = 0
' End If

ldiff = ((Worksheets("revenue").Range("a21") / 0.63) - Cells(19 + k, 3)) / Range("c9")
hdiff = ((Worksheets("revenue").Range("a22") / 0.63) - Cells(19 + k, 3)) / Range("c9")
 light = WorksheetFunction.NormSDist(ldiff) * Worksheets("revenue").Range("d21")
 heavy = (1 - WorksheetFunction.NormSDist(hdiff)) * Worksheets("revenue").Range("d22")
  Cells(19 + k, 16) = light
  Cells(19 + k, 17) = heavy

If Range("n9") = 2 Then
```

```
Cells(19 + k, 2) = Worksheets("revenue").Range("d9") + _
 (yg1 * yield1) + _
 (yg2 * yield2) + _
 (yg4 * yield4) + _
 (yg5 * yield5) + _
 (qg1 * prime) + _
 (qg3 * selct) + _
 (qg4 * stndrd) + light + heavy
ElseIf Range("n9") = 1 Then
 Cells(19 + k, 2) = Worksheets("revenue").Range("d9") + _
  (Cells(19 + k, 7) * yield1) + _
  (Cells(19 + k, 8) * yield2) + _
  (Cells(19 + k, 10) * yield4) + _
  (Cells(19 + k, 11) * yield5) + _
  (Cells(19 + k, 12) * prime) + _
  (Cells(19 + k, 14) * selct) + _
  (Cells(19 + k, 15) * stndrd) + light + heavy
End If

Cells(19 + k, 4) = Cells(19 + k, 2) * ((Cells(19 + k, 3) * drspcnt) / 100)

Cells(19 + k, 26) = Cells(19 + k, 4) - Cells(19 + k, 6)

Calculate

If i >= days Then
Worksheets("revenue").Cells(3 + (i - days), 8) = i
Worksheets("revenue").Cells(3 + (i - days), 9) = Range("b17")
Worksheets("revenue").Cells(3 + (i - days), 10) = Range("d17")
Worksheets("revenue").Cells(3 + (i - days), 11) = Range("f17")
Worksheets("revenue").Cells(3 + (i - days), 12) = Range("z17")
Worksheets("revenue").Cells(3 + (i - days), 13) = Worksheets("revenue").Cells(3 + (i - days), 12) / cnt
Worksheets("revenue").Cells(3 + (i - days), 14) = Range("g17")
Worksheets("revenue").Cells(3 + (i - days), 15) = Range("h17")
Worksheets("revenue").Cells(3 + (i - days), 16) = Range("i17")
Worksheets("revenue").Cells(3 + (i - days), 17) = Range("j17")
Worksheets("revenue").Cells(3 + (i - days), 18) = Range("k17")
Worksheets("revenue").Cells(3 + (i - days), 19) = Range("l17")
Worksheets("revenue").Cells(3 + (i - days), 20) = Range("m17")
Worksheets("revenue").Cells(3 + (i - days), 21) = Range("n17")
Worksheets("revenue").Cells(3 + (i - days), 22) = Range("o17")
Worksheets("revenue").Cells(3 + (i - days), 23) = Range("p17") / cnt
Worksheets("revenue").Cells(3 + (i - days), 24) = Range("q17") / cnt
Worksheets("revenue").Cells(3 + (i - days), 25) = Range("c17")
Worksheets("revenue").Cells(3 + (i - days), 26) = Range("m10")

If Range("o11") = 1 Or Range("o11") = 3 Then
Worksheets("revenue").Cells(3 + (i - days), 28) = Range("aa17")
Worksheets("revenue").Cells(3 + (i - days), 27) = Worksheets("revenue").Cells(3 + (i - days), 28) + _
 Worksheets("revenue").Cells(3 + (i - days), 11)
Worksheets("revenue").Cells(3 + (i - days), 29) = Worksheets("revenue").Cells(3 + (i - days), 28) / cnt
End If

If Range("o11") = 2 Or Range("o11") = 3 Then
Worksheets("revenue").Cells(3 + (i - days), 32) = Range("y17")
Worksheets("revenue").Cells(3 + (i - days), 31) = Worksheets("revenue").Cells(3 + (i - days), 32) + _
 Worksheets("revenue").Cells(3 + (i - days), 11)
Worksheets("revenue").Cells(3 + (i - days), 33) = Worksheets("revenue").Cells(3 + (i - days), 32) / cnt
End If
End If
 k = k + 1
 Loop

Worksheets("All info").Range("a1") = Worksheets("revenue").Cells(8, 4) & " Grid - All Cattle - " & Range("m2")
Worksheets("All info").Cells(2 + i, 1) = i
Worksheets("All info").Cells(2 + i, 2) = WorksheetFunction.Average(Worksheets("growth").Range("v19:v1000"))
Worksheets("All info").Cells(2 + i, 3) = WorksheetFunction.Average(Range("w19:w1000"))
Worksheets("All info").Cells(2 + i, 4) = WorksheetFunction.Average(Range("x19:x1000"))
Worksheets("All info").Cells(2 + i, 5) = WorksheetFunction.Average(Range("y19:y1000"))
Worksheets("All info").Cells(2 + i, 6) = WorksheetFunction.Average(Range("z19:z1000"))
```

```
Worksheets("All info").Cells(2 + i, 7) = WorksheetFunction.Average(Range("aa19:aa1000"))
If i > 1 Then
 Worksheets("All info").Cells(2 + i, 8) = (WorksheetFunction.Sum(Range("d19:d1000")) - prev) _
  / (WorksheetFunction.Sum(Range("c19:c1000")) - ptwght)
 Worksheets("All info").Cells(2 + i, 9) = (WorksheetFunction.Sum(Range("f19:f1000")) - pcost) _
  / (WorksheetFunction.Sum(Range("c19:c1000")) - ptwght)
End If

'If i = 98 Or i = 105 Or i = 112 Or i = 119 Or i = 126 Or i = 133 Or i = 140 Or i = 147 Or i = 154 Or i = 161 Or i = 168 Then
' Worksheets("cog").Cells(2 + one, 2) = Cells(18 + k, 3)
' Worksheets("cog").Cells(2 + one, 3) = Range("f19") / (Range("c19") - Range("a19"))
' Worksheets("cog").Cells(2 + one, 5) = (Range("f19") - prevcost) / (Range("c19") - pweight)
' one = one + 1
'End If

'If i = 91 Or i = 98 Or i = 105 Or i = 112 Or i = 119 Or i = 126 Or i = 133 Or i = 140 Or i = 147 Or i = 154 Or i = 161 Then
' pweight = Range("c19")
' prevcost = Range("f19")
'End If
Next i

' copies optimal grid dof information to a different sheet
For j = 0 To (dof - days - 1)
 If j = 0 Then
  Max = Worksheets("revenue").Cells(3, 12)
  ElseIf j > 0 Then
   If Worksheets("revenue").Cells(3 + j, 12) > Max Then
    Max = Worksheets("revenue").Cells(3 + j, 12)
     Else: Max = Max
   End If
 End If
Next j

j = 0
 Do Until Worksheets("revenue").Cells(3 + j, 8) = Empty
  If Worksheets("revenue").Cells(3 + j, 12) = Max Then
   Worksheets("revenue").Cells(3 + j, 7) = "*"
  End If
  If Worksheets("revenue").Cells(3 + j, 7) = "*" And Worksheets("revenue").Cells(3 + (j - Start + 1), 7) = "*" Then
   Worksheets("revenue").Cells(3 + j, 7) = "*"
   Worksheets("revenue").Cells(3 + (j - Start + 1), 7) = ""
  End If
  If Worksheets("revenue").Cells(3 + j, 7) = "*" Then
   Worksheets("All grid").Range("a1") = Worksheets("revenue").Cells(8, 4) & " - All Cattle - " & Range("m2")
   Worksheets("All grid").Range("d4") = cnt
   Worksheets("All grid").Range("d5") = Range("i1")
   Worksheets("All grid").Range("d6") = Range("i2")
   Worksheets("All grid").Range("d7") = Range("d3")
   Worksheets("All grid").Range("d8") = Worksheets("revenue").Range("d9")
   Worksheets("All grid").Range("a12") = Worksheets("revenue").Cells(3 + j, 8)
   Worksheets("All grid").Range("b12") = Worksheets("revenue").Cells(3 + j, 9)
   Worksheets("All grid").Range("c12") = Worksheets("revenue").Cells(3 + j, 10)
   Worksheets("All grid").Range("d12") = Worksheets("revenue").Cells(3 + j, 11)
   Worksheets("All grid").Range("e12") = Worksheets("revenue").Cells(3 + j, 12)
   Worksheets("All grid").Range("f12") = Worksheets("revenue").Cells(3 + j, 13)

   Worksheets("All grid").Range("a17") = Worksheets("revenue").Cells(3 + j, 14)
   Worksheets("All grid").Range("b17") = Worksheets("revenue").Cells(3 + j, 15)
   Worksheets("All grid").Range("c17") = Worksheets("revenue").Cells(3 + j, 16)
   Worksheets("All grid").Range("d17") = Worksheets("revenue").Cells(3 + j, 17)
   Worksheets("All grid").Range("e17") = Worksheets("revenue").Cells(3 + j, 18)

   Worksheets("All grid").Range("a22") = Worksheets("revenue").Cells(3 + j, 19)
   Worksheets("All grid").Range("b22") = Worksheets("revenue").Cells(3 + j, 20)
   Worksheets("All grid").Range("c22") = Worksheets("revenue").Cells(3 + j, 21)
   Worksheets("All grid").Range("d22") = Worksheets("revenue").Cells(3 + j, 22)

   Worksheets("All grid").Range("a27") = Worksheets("revenue").Cells(3 + j, 23)
   Worksheets("All grid").Range("b27") = Worksheets("revenue").Cells(3 + j, 24)
   Worksheets("All grid").Range("c27") = Worksheets("revenue").Cells(3 + j, 25)
```

```
 End If
 j = j + 1
 Loop

' copies optimal cash dof information to a different sheet
If Range("o11") = 1 Or Range("o11") = 3 Then
For j = 0 To (dof - days - 1)
 If j = 0 Then
  Max = Worksheets("revenue").Cells(3, 28)
  ElseIf j > 0 Then
   If Worksheets("revenue").Cells(3 + j, 28) > Max Then
    Max = Worksheets("revenue").Cells(3 + j, 28)
     Else: Max = Max
   End If
 End If
Next j

j = 0
 Do Until Worksheets("revenue").Cells(3 + j, 8) = Empty
  If Worksheets("revenue").Cells(3 + j, 28) = Max Then
   Worksheets("revenue").Cells(3 + j, 26) = "*"
  End If
  If Worksheets("revenue").Cells(3 + j, 26) = "*" And Worksheets("revenue").Cells(3 + (j - Start + 1), 26) = "*" Then
   Worksheets("revenue").Cells(3 + j, 26) = "*"
   Worksheets("revenue").Cells(3 + (j - Start + 1), 26) = ""
  End If
  If Worksheets("revenue").Cells(3 + j, 26) = "*" Then
   Worksheets("All cash").Range("a1") = "Cash - All Cattle - " & Range("m2")
   Worksheets("All cash").Range("d4") = cnt
   Worksheets("All cash").Range("d5") = Range("i1")
   Worksheets("All cash").Range("d6") = Range("i2")
   Worksheets("All cash").Range("d7") = Range("d3")
   Worksheets("All cash").Range("d8") = Worksheets("revenue").Range("d26")
   Worksheets("All cash").Range("a12") = Worksheets("revenue").Cells(3 + j, 8)
   Worksheets("All cash").Range("b12") = Worksheets("revenue").Cells(3 + j, 27)
   Worksheets("All cash").Range("c12") = Worksheets("revenue").Cells(3 + j, 11)
   Worksheets("All cash").Range("d12") = Worksheets("revenue").Cells(3 + j, 28)
   Worksheets("All cash").Range("e12") = Worksheets("revenue").Cells(3 + j, 29)

   Worksheets("All cash").Range("a17") = Worksheets("revenue").Cells(3 + j, 14)
   Worksheets("All cash").Range("b17") = Worksheets("revenue").Cells(3 + j, 15)
   Worksheets("All cash").Range("c17") = Worksheets("revenue").Cells(3 + j, 16)
   Worksheets("All cash").Range("d17") = Worksheets("revenue").Cells(3 + j, 17)
   Worksheets("All cash").Range("e17") = Worksheets("revenue").Cells(3 + j, 18)

   Worksheets("All cash").Range("a22") = Worksheets("revenue").Cells(3 + j, 19)
   Worksheets("All cash").Range("b22") = Worksheets("revenue").Cells(3 + j, 20)
   Worksheets("All cash").Range("c22") = Worksheets("revenue").Cells(3 + j, 21)
   Worksheets("All cash").Range("d22") = Worksheets("revenue").Cells(3 + j, 22)

   Worksheets("All cash").Range("a27") = Worksheets("revenue").Cells(3 + j, 23)
   Worksheets("All cash").Range("b27") = Worksheets("revenue").Cells(3 + j, 24)
   Worksheets("All cash").Range("c27") = Worksheets("revenue").Cells(3 + j, 25)
  End If
 j = j + 1
 Loop
 End If

If Range("o11") = 2 Or Range("o11") = 3 Then
For j = 0 To (dof - days - 1)
 If j = 0 Then
  Max = Worksheets("revenue").Cells(3, 32)
  ElseIf j > 0 Then
   If Worksheets("revenue").Cells(3 + j, 32) > Max Then
    Max = Worksheets("revenue").Cells(3 + j, 32)
     Else: Max = Max
   End If
 End If
Next j
```

```
j = 0
 Do Until Worksheets("revenue").Cells(3 + j, 8) = Empty
  If Worksheets("revenue").Cells(3 + j, 32) = Max Then
   Worksheets("revenue").Cells(3 + j, 30) = "*"
  End If
  If Worksheets("revenue").Cells(3 + j, 30) = "*" And Worksheets("revenue").Cells(3 + (j - Start + 1), 30) = "*" Then
   Worksheets("revenue").Cells(3 + j, 30) = "*"
   Worksheets("revenue").Cells(3 + (j - Start + 1), 30) = ""
  End If
  If Worksheets("revenue").Cells(3 + j, 30) = "*" Then
   Worksheets("All dressed").Range("a1") = "Dressed - All Cattle - " & Range("m2")
   Worksheets("All dressed").Range("d4") = cnt
   Worksheets("All dressed").Range("d5") = Range("i1")
   Worksheets("All dressed").Range("d6") = Range("i2")
   Worksheets("All dressed").Range("d7") = Range("d3")
   Worksheets("All dressed").Range("d8") = Worksheets("revenue").Range("d25")
   Worksheets("All dressed").Range("a12") = Worksheets("revenue").Cells(3 + j, 8)
   Worksheets("All dressed").Range("b12") = Worksheets("revenue").Cells(3 + j, 31)
   Worksheets("All dressed").Range("c12") = Worksheets("revenue").Cells(3 + j, 11)
   Worksheets("All dressed").Range("d12") = Worksheets("revenue").Cells(3 + j, 32)
   Worksheets("All dressed").Range("e12") = Worksheets("revenue").Cells(3 + j, 33)

   Worksheets("All dressed").Range("a17") = Worksheets("revenue").Cells(3 + j, 14)
   Worksheets("All dressed").Range("b17") = Worksheets("revenue").Cells(3 + j, 15)
   Worksheets("All dressed").Range("c17") = Worksheets("revenue").Cells(3 + j, 16)
   Worksheets("All dressed").Range("d17") = Worksheets("revenue").Cells(3 + j, 17)
   Worksheets("All dressed").Range("e17") = Worksheets("revenue").Cells(3 + j, 18)

   Worksheets("All dressed").Range("a22") = Worksheets("revenue").Cells(3 + j, 19)
   Worksheets("All dressed").Range("b22") = Worksheets("revenue").Cells(3 + j, 20)
   Worksheets("All dressed").Range("c22") = Worksheets("revenue").Cells(3 + j, 21)
   Worksheets("All dressed").Range("d22") = Worksheets("revenue").Cells(3 + j, 22)

   Worksheets("All dressed").Range("a27") = Worksheets("revenue").Cells(3 + j, 23)
   Worksheets("All dressed").Range("b27") = Worksheets("revenue").Cells(3 + j, 24)
   Worksheets("All dressed").Range("c27") = Worksheets("revenue").Cells(3 + j, 25)
  End If
 j = j + 1
 Loop
 End If

End Sub
```

Appendix C

Visual Basic Program for the Pen Growth Model

The following is the Visual Basic code used to grow cattle, sort them into pens based on their placement weight, and sell each pen when profits are maximized.

```
Sub Pen()
Worksheets("growth").Activate
 Range("b19:ab1000").ClearContents
Worksheets("revenue").Range("g3:ah1000").ClearContents
Worksheets("pen grid").Range("d3:d6").ClearContents
Worksheets("pen grid").Range("a10:j18").ClearContents
Worksheets("pen grid").Range("a23:f31").ClearContents
Worksheets("pen grid").Range("a35:e43").ClearContents
Worksheets("pen grid").Range("a47:d55").ClearContents
Worksheets("pen cash").Range("d3:d6").ClearContents
Worksheets("pen cash").Range("a10:g18").ClearContents
Worksheets("pen cash").Range("a23:f31").ClearContents
Worksheets("pen cash").Range("a35:e43").ClearContents
Worksheets("pen cash").Range("a47:d55").ClearContents
Worksheets("pen dressed").Range("d3:d6").ClearContents
Worksheets("pen dressed").Range("a10:g18").ClearContents
Worksheets("pen dressed").Range("a23:f31").ClearContents
Worksheets("pen dressed").Range("a35:e43").ClearContents
Worksheets("pen dressed").Range("a47:d55").ClearContents
Worksheets("pen info").Range("a2:cc2").ClearContents
Worksheets("pen info").Range("a4:cc1000").ClearContents
Worksheets("changes").Range("a2:aj2").ClearContents
Worksheets("changes").Range("a4:aj1000").ClearContents

Calculate

'Dim days As Integer
' days = InputBox("On what DOF do you want to start recording? 1 to Max Days on Feed", Recording, 115)

sorting = Range("d12")
If sorting = 0 Then
 dof1 = Range("d13")
  Else
   dof1 = sorting - 1
   dof2 = Range("d13")
End If

frmsize = Range("c5")
grwthint = Range("c8")

' first sort
a = 0
cnt4 = 0
cnt5 = 0
cnt6 = 0
cnt7 = 0
cnt8 = 0
cnt9 = 0
cnt10 = 0
cnt11 = 0
Do Until Cells(19 + a, 1) = Empty
Randomize
 If Cells(19 + a, 1) < 500 Then
```

```
 Cells(19 + a, 28) = 4
 cnt4 = cnt4 + 1
 Cells(19 + a, 20) = Rnd
 Cells(19 + a, 21) = Rnd
  ElseIf Cells(19 + a, 1) >= 500 And Cells(19 + a, 1) < 600 Then
   Cells(19 + a, 28) = 5
   cnt5 = cnt5 + 1
   Cells(19 + a, 20) = Rnd
   Cells(19 + a, 21) = Rnd
    ElseIf Cells(19 + a, 1) >= 600 And Cells(19 + a, 1) < 700 Then
     Cells(19 + a, 28) = 6
     cnt6 = cnt6 + 1
     Cells(19 + a, 20) = Rnd
     Cells(19 + a, 21) = Rnd
      ElseIf Cells(19 + a, 1) >= 700 And Cells(19 + a, 1) < 800 Then
      Cells(19 + a, 28) = 7
      cnt7 = cnt7 + 1
      Cells(19 + a, 20) = Rnd
      Cells(19 + a, 21) = Rnd
       ElseIf Cells(19 + a, 1) >= 800 And Cells(19 + a, 1) < 900 Then
       Cells(19 + a, 28) = 8
       cnt8 = cnt8 + 1
       Cells(19 + a, 20) = Rnd
       Cells(19 + a, 21) = Rnd
        ElseIf Cells(19 + a, 1) >= 900 And Cells(19 + a, 1) < 1000 Then
        Cells(19 + a, 28) = 9
        cnt9 = cnt9 + 1
        Cells(19 + a, 20) = Rnd
        Cells(19 + a, 21) = Rnd
         ElseIf Cells(19 + a, 1) >= 1000 And Cells(19 + a, 1) < 1100 Then
         Cells(19 + a, 28) = 10
         cnt10 = cnt10 + 1
         Cells(19 + a, 20) = Rnd
         Cells(19 + a, 21) = Rnd
          ElseIf Cells(19 + a, 1) >= 1100 Then
          Cells(19 + a, 28) = 11
          cnt11 = cnt11 + 1
          Cells(19 + a, 20) = Rnd
          Cells(19 + a, 21) = Rnd
End If
a = a + 1
Loop

Range(Cells(19, 1), Cells(19 + a - 1, 30)).Select
 Selection.Sort Key1:=Range("ab19"), Order1:=xlAscending, Header:=xlGuess, _
  OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom
Range("B19").Select

p = 0
pcnt = 0
For d = 4 To 11
 For i = 1 To dofl
  If d = 4 Then
   k = 0
   m = 0
   cnt = cnt4
   begin = Range("d13") - 30
   finish = Range("d13")
   If cnt = 0 Then GoTo none
    ElseIf d = 5 Then
    k = cnt4
    m = cnt4
    cnt = cnt5
    begin = Range("d13") - 50
    finish = Range("d13") - 20
    If cnt = 0 Then GoTo none
     ElseIf d = 6 Then
     k = cnt4 + cnt5
     m = cnt4 + cnt5
     cnt = cnt6
```

```
    begin = Range("d13") - 70
    finish = Range("d13") - 40
    If cnt = 0 Then GoTo none
     ElseIf d = 7 Then
      k = cnt4 + cnt5 + cnt6
      m = cnt4 + cnt5 + cnt6
      cnt = cnt7
      begin = Range("d13") - 90
      finish = Range("d13") - 60
      If cnt = 0 Then GoTo none
       ElseIf d = 8 Then
        k = cnt4 + cnt5 + cnt6 + cnt7
        m = cnt4 + cnt5 + cnt6 + cnt7
        cnt = cnt8
        begin = Range("d13") - 100
        finish = Range("d13") - 70
        If cnt = 0 Then GoTo none
         ElseIf d = 9 Then
          k = cnt4 + cnt5 + cnt6 + cnt7 + cnt8
          m = cnt4 + cnt5 + cnt6 + cnt7 + cnt8
          cnt = cnt9
          begin = Range("d13") - 110
          finish = Range("d13") - 80
          If cnt = 0 Then GoTo none
           ElseIf d = 10 Then
            k = cnt4 + cnt5 + cnt6 + cnt7 + cnt8 + cnt9
            m = cnt4 + cnt5 + cnt6 + cnt7 + cnt8 + cnt9
            cnt = cnt10
            begin = Range("d13") - 120
            finish = Range("d13") - 90
            If cnt = 0 Then GoTo none
             ElseIf d = 11 Then
              k = cnt4 + cnt5 + cnt6 + cnt7 + cnt8 + cnt9 + cnt10
              m = cnt4 + cnt5 + cnt6 + cnt7 + cnt8 + cnt9 + cnt10
              cnt = cnt11
              begin = Range("d13") - 130
              finish = Range("d13") - 100
              If cnt = 0 Then GoTo none
  End If

' previous revenue used to calculate marginal grid revenue
prev = WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 4), Cells(19 + (m - 1) + cnt, 4)))
' previous costs used to calculate marginal costs
pcost = WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 6), Cells(19 + (m - 1) + cnt, 6)))
' previous weight used to calculate marginal revenue/costs
ptwght = WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 3), Cells(19 + (m - 1) + cnt, 3)))

ccnt = 0
Do While Cells(19 + k, 28) = d
 Range("d14") = i
 Range("d15") = d
 Range("e15") = ccnt + 1

' calculations for specified number of days on feed
Call growth(k, i, frmsize, grwthint)

If sorting <> 0 Then
 GoTo skipto
  Else
   Call revenue(i, k, pcnt, begin, finish, p, d, m, cnt)
End If

skipto:
 k = k + 1
 ccnt = ccnt + 1
 Loop
 Calculate
 If sorting = 0 Then Call info(d, i, m, cnt, prev, pcost, ptwght)
Next i
```

```
 p = p + 1
 pcnt = pcnt + 1
none:
Next d

' second sort after specified days on feed
If sorting <> 0 Then
a = 0
cnt6 = 0
cnt7 = 0
cnt8 = 0
cnt9 = 0
cnt10 = 0
cnt11 = 0
cnt12 = 0
cnt13 = 0
cnt14 = 0
cnt15 = 0
Do Until Cells(19 + a, 3) = Empty
 If Cells(19 + a, 3) < 700 Then
  Cells(19 + a, 28) = 6
  cnt6 = cnt6 + 1
   ElseIf Cells(19 + a, 3) >= 700 And Cells(19 + a, 3) < 800 Then
    Cells(19 + a, 28) = 7
    cnt7 = cnt7 + 1
     ElseIf Cells(19 + a, 3) >= 800 And Cells(19 + a, 3) < 900 Then
      Cells(19 + a, 28) = 8
      cnt8 = cnt8 + 1
       ElseIf Cells(19 + a, 3) >= 900 And Cells(19 + a, 3) < 1000 Then
        Cells(19 + a, 28) = 9
        cnt9 = cnt9 + 1
         ElseIf Cells(19 + a, 3) >= 1000 And Cells(19 + a, 3) < 1100 Then
          Cells(19 + a, 28) = 10
          cnt10 = cnt10 + 1
           ElseIf Cells(19 + a, 3) >= 1100 And Cells(19 + a, 3) < 1200 Then
            Cells(19 + a, 28) = 11
            cnt11 = cnt11 + 1
             ElseIf Cells(19 + a, 3) >= 1200 And Cells(19 + a, 3) < 1300 Then
              Cells(19 + a, 28) = 12
              cnt12 = cnt12 + 1
               ElseIf Cells(19 + a, 3) >= 1300 And Cells(19 + a, 3) < 1400 Then
                Cells(19 + a, 28) = 13
                cnt13 = cnt13 + 1
                 ElseIf Cells(19 + a, 3) >= 1400 And Cells(19 + a, 3) < 1500 Then
                  Cells(19 + a, 28) = 14
                  cnt14 = cnt14 + 1
                   ElseIf Cells(19 + a, 3) >= 1500 Then
                    Cells(19 + a, 28) = 15
                    cnt15 = cnt15 + 1
 End If
a = a + 1
Loop

Range(Cells(19, 1), Cells(19 + a - 1, 30)).Select
 Selection.Sort Key1:=Range("ab19"), Order1:=xlAscending, Header:=xlGuess, _
  OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom
Range("B19").Select

p = 0
pcnt = 0
 For d = 6 To 15
  For i = sorting To dof2
  If d = 6 Then
   k = 0
   m = 0
   cnt = cnt6
   begin = Range("d13") - 30
   finish = Range("d13")
    If cnt = 0 Then GoTo none2
     ElseIf d = 7 Then
```

```
k = cnt6
m = cnt6
cnt = cnt7
begin = Range("d13") - 50
finish = Range("d13") - 20
If cnt = 0 Then GoTo none2
 ElseIf d = 8 Then
  k = cnt6 + cnt7
  m = cnt6 + cnt7
  cnt = cnt8
  begin = Range("d13") - 60
  finish = Range("d13") - 30
  If cnt = 0 Then GoTo none2
   ElseIf d = 9 Then
    k = cnt6 + cnt7 + cnt8
    m = cnt6 + cnt7 + cnt8
    cnt = cnt9
    begin = Range("d13") - 70
    finish = Range("d13") - 40
    If cnt = 0 Then GoTo none2
     ElseIf d = 10 Then
      k = cnt6 + cnt7 + cnt8 + cnt9
      m = cnt6 + cnt7 + cnt8 + cnt9
      cnt = cnt10
      begin = Range("d13") - 90
      finish = Range("d13") - 60
      If cnt = 0 Then GoTo none2
       ElseIf d = 11 Then
        k = cnt6 + cnt7 + cnt8 + cnt9 + cnt10
        m = cnt6 + cnt7 + cnt8 + cnt9 + cnt10
        cnt = cnt11
        begin = Range("d13") - 100
        finish = Range("d13") - 70
        If cnt = 0 Then GoTo none2
         ElseIf d = 12 Then
          k = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11
          m = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11
          cnt = cnt12
          begin = Range("d13") - 120
          finish = Range("d13") - 90
          If cnt = 0 Then GoTo none2
           ElseIf d = 13 Then
            k = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12
            m = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12
            cnt = cnt13
            begin = Range("d13") - 130
            finish = Range("d13") - 100
            If cnt = 0 Then GoTo none2
             ElseIf d = 14 Then
              k = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12 + cnt13
              m = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12 + cnt13
              cnt = cnt14
              begin = Range("d13") - 140
              finish = Range("d13") - 110
              If cnt = 0 Then GoTo none2
               ElseIf d = 15 Then
                k = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12 + cnt13 + cnt14
                m = cnt6 + cnt7 + cnt8 + cnt9 + cnt10 + cnt11 + cnt12 + cnt13 + cnt14
                cnt = cnt15
                begin = Range("d13") - 150
                finish = Range("d13") - 120
                If cnt = 0 Then GoTo none2
End If

ccnt = 0
Do While Cells(19 + k, 28) = d
 Range("d14") = i
 Range("d15") = d
 Range("e15") = ccnt + 1
```

```
' calculations for specified number of days on feed
Call growth(k, i, frmsize, grwthint)

Call revenue(i, k, pcnt, begin, finish, p, d, m, cnt)

 k = k + 1
 ccnt = ccnt + 1
 Loop
 Calculate

Next i
 p = p + 1
 pcnt = pcnt + 1
none2:
Next d
End If

k = 0
Do Until Cells(19 + k, 28) = Empty
 If k = 0 Then
  lower = Cells(19 + k, 28)
  upper = Cells(19 + k, 28)
 End If
 If Cells(19 + k, 28) < lower Then
  lower = Cells(19 + k, 28)
 End If
 If Cells(19 + k, 28) > upper Then
  upper = Cells(19 + k, 28)
 End If
k = k + 1
Loop

k = 0
pcnt = 0
For d = lower To upper
j = 0
If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) <> d Then GoTo none3
 Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
 If j = 0 Then
  Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 13)
   ElseIf j > 0 Then
    If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 13) > Max Then
     Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 13)
      Else: Max = Max
    End If
  End If
  j = j + 1
  Loop

 j = 0
 Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
  If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 13) = Max Then
   Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 7) = "*"
  End If
 j = j + 1
 Loop
pcnt = pcnt + 1
k = k + 1
none3:
Next d

j = 0
Do Until Worksheets("revenue").Cells(3 + j, 8) = Empty
 If Worksheets("revenue").Cells(3 + j - 1, 7) = "*" And Worksheets("revenue").Cells(3 + j, 7) = "*" Then
  Worksheets("revenue").Cells(3 + j - 1, 7) = "*"
  Worksheets("revenue").Cells(3 + j, 7) = " "
 End If

  iy1 = 82.0939
  iy2 = 84.8634
```

```
iy3 = 87.4282
iy4 = 89.9601
ygv1 = -8.7489
ygv2 = -2.3111
 var1 = Log(Worksheets("revenue").Cells(3 + j, 26))
 var2 = Log(Worksheets("revenue").Cells(3 + j, 9) ^ 2)
ufy1 = iy1 + (ygv1 * var1) + (ygv2 * var2)
ufy2 = iy2 + (ygv1 * var1) + (ygv2 * var2)
ufy3 = iy3 + (ygv1 * var1) + (ygv2 * var2)
ufy4 = iy4 + (ygv1 * var1) + (ygv2 * var2)

iq1 = -35.9428
iq2 = -30.6281
iq3 = -27.9
qgva = 2.7558
qgvb = 1.148
 vara = Log(Worksheets("revenue").Cells(3 + j, 26))
 varb = Log(Worksheets("revenue").Cells(3 + j, 9) ^ 2)
ufq1 = iq1 + (qgva * vara) + (qgvb * varb)
ufq2 = iq2 + (qgva * vara) + (qgvb * varb)
ufq3 = iq3 + (qgva * vara) + (qgvb * varb)

Worksheets("revenue").Cells(3 + j, 15) = Exp(ufy1) / (1 + Exp(ufy1))
Worksheets("revenue").Cells(3 + j, 16) = (Exp(ufy2) / (1 + Exp(ufy2))) - _
 (Exp(ufy1) / (1 + Exp(ufy1)))
Worksheets("revenue").Cells(3 + j, 17) = (Exp(ufy3) / (1 + Exp(ufy3))) - _
 (Exp(ufy2) / (1 + Exp(ufy2)))
Worksheets("revenue").Cells(3 + j, 18) = (Exp(ufy4) / (1 + Exp(ufy4))) - _
 (Exp(ufy3) / (1 + Exp(ufy3)))
Worksheets("revenue").Cells(3 + j, 19) = 1 - (Exp(ufy4) / (1 + Exp(ufy4)))

Worksheets("revenue").Cells(3 + j, 20) = Exp(ufq1) / (1 + Exp(ufq1))
Worksheets("revenue").Cells(3 + j, 21) = (Exp(ufq2) / (1 + Exp(ufq2))) - _
 (Exp(ufq1) / (1 + Exp(ufq1)))
Worksheets("revenue").Cells(3 + j, 22) = (Exp(ufq3) / (1 + Exp(ufq3))) - _
 (Exp(ufq2) / (1 + Exp(ufq2)))
Worksheets("revenue").Cells(3 + j, 23) = 1 - (Exp(ufq3) / (1 + Exp(ufq3)))

j = j + 1
Loop

k = 0
m = 0
Do While Worksheets("revenue").Cells(3 + m, 8) <> Empty
If Worksheets("revenue").Cells(3 + m, 7) = "*" Then
 Worksheets("pen grid").Range("a1") = Worksheets("revenue").Cells(8, 4) & " - Pen Level - " & Range("m3") & " - " & Range("m2")
 Worksheets("pen grid").Range("d3") = Range("i1")
 Worksheets("pen grid").Range("d4") = Range("i2")
 Worksheets("pen grid").Range("d5") = Range("d3")
 Worksheets("pen grid").Range("d6") = Worksheets("revenue").Range("d9")

 Worksheets("pen grid").Cells(10 + k, 1) = Worksheets("revenue").Cells(3 + m, 8)
 Worksheets("pen grid").Cells(10 + k, 3) = Worksheets("revenue").Cells(3 + m, 9)
 Worksheets("pen grid").Cells(10 + k, 4) = Worksheets("revenue").Cells(3 + m, 10)
 Worksheets("pen grid").Cells(10 + k, 5) = Worksheets("revenue").Cells(3 + m, 11)
 Worksheets("pen grid").Cells(10 + k, 6) = Worksheets("revenue").Cells(3 + m, 12)
 Worksheets("pen grid").Cells(10 + k, 7) = Worksheets("revenue").Cells(3 + m, 13)
 Worksheets("pen grid").Cells(10 + k, 8) = Worksheets("revenue").Cells(3 + m, 14)

 Worksheets("pen grid").Cells(23 + k, 1) = Worksheets("revenue").Cells(3 + m, 8)
 Worksheets("pen grid").Cells(23 + k, 2) = Worksheets("revenue").Cells(3 + m, 15)
 Worksheets("pen grid").Cells(23 + k, 3) = Worksheets("revenue").Cells(3 + m, 16)
 Worksheets("pen grid").Cells(23 + k, 4) = Worksheets("revenue").Cells(3 + m, 17)
 Worksheets("pen grid").Cells(23 + k, 5) = Worksheets("revenue").Cells(3 + m, 18)
 Worksheets("pen grid").Cells(23 + k, 6) = Worksheets("revenue").Cells(3 + m, 19)

 Worksheets("pen grid").Cells(35 + k, 1) = Worksheets("revenue").Cells(3 + m, 8)
 Worksheets("pen grid").Cells(35 + k, 2) = Worksheets("revenue").Cells(3 + m, 20)
 Worksheets("pen grid").Cells(35 + k, 3) = Worksheets("revenue").Cells(3 + m, 21)
 Worksheets("pen grid").Cells(35 + k, 4) = Worksheets("revenue").Cells(3 + m, 22)
```

```
Worksheets("pen grid").Cells(35 + k, 5) = Worksheets("revenue").Cells(3 + m, 23)

Worksheets("pen grid").Cells(47 + k, 1) = Worksheets("revenue").Cells(3 + m, 8)
Worksheets("pen grid").Cells(47 + k, 2) = Worksheets("revenue").Cells(3 + m, 24)
Worksheets("pen grid").Cells(47 + k, 3) = Worksheets("revenue").Cells(3 + m, 25)
Worksheets("pen grid").Cells(47 + k, 4) = Worksheets("revenue").Cells(3 + m, 26)

k = k + 1
End If
m = m + 1
Loop

' copies optimal cash dof information to a different sheet
If Range("o11") = 1 Or Range("o11") = 3 Then
k = 0
pcnt = 0
For d = lower To upper
j = 0
If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) <> d Then GoTo none4
Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
If j = 0 Then
 Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 29)
 ElseIf j > 0 Then
  If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 29) > Max Then
   Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 29)
    Else: Max = Max
  End If
 End If
j = j + 1
Loop

j = 0
Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
 If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 29) = Max Then
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 27) = "*"
 End If
j = j + 1
Loop

j = 0
Do Until Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = Empty
 If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k - 1, 27) = "*" And _
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 27) = "*" Then
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k - 1, 27) = "*"
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 27) = " "
 End If
j = j + 1
Loop

pcnt = pcnt + 1
k = k + 1
none4:
Next d

k = 0
m = 0
Do While Worksheets("revenue").Cells(3 + k, 8) <> Empty
If Worksheets("revenue").Cells(3 + k, 27) = "*" Then
 Worksheets("pen cash").Range("a1") = "Cash Info - Pen Level - " & Range("m3") & " - " & Range("m2")
 Worksheets("pen cash").Range("d3") = Range("i1")
 Worksheets("pen cash").Range("d4") = Range("i2")
 Worksheets("pen cash").Range("d5") = Range("d3")
 Worksheets("pen cash").Range("d6") = Worksheets("revenue").Range("d25")

 Worksheets("pen cash").Cells(10 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
 Worksheets("pen cash").Cells(10 + m, 3) = Worksheets("revenue").Cells(3 + k, 9)
 Worksheets("pen cash").Cells(10 + m, 4) = Worksheets("revenue").Cells(3 + k, 28)
 Worksheets("pen cash").Cells(10 + m, 5) = Worksheets("revenue").Cells(3 + k, 12)
 Worksheets("pen cash").Cells(10 + m, 6) = Worksheets("revenue").Cells(3 + k, 29)
 Worksheets("pen cash").Cells(10 + m, 7) = Worksheets("revenue").Cells(3 + k, 30)
```

```
 Worksheets("pen cash").Cells(23 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
 Worksheets("pen cash").Cells(23 + m, 2) = Worksheets("revenue").Cells(3 + k, 15)
 Worksheets("pen cash").Cells(23 + m, 3) = Worksheets("revenue").Cells(3 + k, 16)
 Worksheets("pen cash").Cells(23 + m, 4) = Worksheets("revenue").Cells(3 + k, 17)
 Worksheets("pen cash").Cells(23 + m, 5) = Worksheets("revenue").Cells(3 + k, 18)
 Worksheets("pen cash").Cells(23 + m, 6) = Worksheets("revenue").Cells(3 + k, 19)

 Worksheets("pen cash").Cells(35 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
 Worksheets("pen cash").Cells(35 + m, 2) = Worksheets("revenue").Cells(3 + k, 20)
 Worksheets("pen cash").Cells(35 + m, 3) = Worksheets("revenue").Cells(3 + k, 21)
 Worksheets("pen cash").Cells(35 + m, 4) = Worksheets("revenue").Cells(3 + k, 22)
 Worksheets("pen cash").Cells(35 + m, 5) = Worksheets("revenue").Cells(3 + k, 23)

 Worksheets("pen cash").Cells(47 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
 Worksheets("pen cash").Cells(47 + m, 2) = Worksheets("revenue").Cells(3 + k, 24)
 Worksheets("pen cash").Cells(47 + m, 3) = Worksheets("revenue").Cells(3 + k, 25)
 Worksheets("pen cash").Cells(47 + m, 4) = Worksheets("revenue").Cells(3 + k, 26)
  m = m + 1
  End If
  k = k + 1
 Loop
 End If

' copies optimal dressed dof information to a different sheet
If Range("o11") = 2 Or Range("o11") = 3 Then
k = 0
pcnt = 0
For d = lower To upper
j = 0
If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) <> d Then GoTo none5
 Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
 If j = 0 Then
  Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 33)
   ElseIf j > 0 Then
   If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 33) > Max Then
    Max = Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 33)
     Else: Max = Max
   End If
  End If
  j = j + 1
  Loop

 j = 0
 Do While Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = d
  If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 33) = Max Then
   Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 31) = "*"
  End If
 j = j + 1
 Loop

j = 0
Do Until Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 8) = Empty
 If Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k - 1, 31) = "*" And _
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 31) = "*" Then
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k - 1, 31) = "*"
  Worksheets("revenue").Cells(3 + (pcnt * 30) + j + k, 31) = " "
 End If
j = j + 1
Loop

pcnt = pcnt + 1
k = k + 1
none5:
Next d

k = 0
m = 0
Do While Worksheets("revenue").Cells(3 + k, 8) <> Empty
 If Worksheets("revenue").Cells(3 + k, 31) = "*" Then
```

```
Worksheets("pen dressed").Range("a1") = "Dressed Info - Pen Level - " & Range("m3") & " - " & Range("m2")
Worksheets("pen dressed").Range("d3") = Range("i1")
Worksheets("pen dressed").Range("d4") = Range("i2")
Worksheets("pen dressed").Range("d5") = Range("d3")
Worksheets("pen dressed").Range("d6") = Worksheets("revenue").Range("d24")

Worksheets("pen dressed").Cells(10 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
Worksheets("pen dressed").Cells(10 + m, 3) = Worksheets("revenue").Cells(3 + k, 9)
Worksheets("pen dressed").Cells(10 + m, 4) = Worksheets("revenue").Cells(3 + k, 32)
Worksheets("pen dressed").Cells(10 + m, 5) = Worksheets("revenue").Cells(3 + k, 12)
Worksheets("pen dressed").Cells(10 + m, 6) = Worksheets("revenue").Cells(3 + k, 33)
Worksheets("pen dressed").Cells(10 + m, 7) = Worksheets("revenue").Cells(3 + k, 34)

Worksheets("pen dressed").Cells(23 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
Worksheets("pen dressed").Cells(23 + m, 2) = Worksheets("revenue").Cells(3 + k, 15)
Worksheets("pen dressed").Cells(23 + m, 3) = Worksheets("revenue").Cells(3 + k, 16)
Worksheets("pen dressed").Cells(23 + m, 4) = Worksheets("revenue").Cells(3 + k, 17)
Worksheets("pen dressed").Cells(23 + m, 5) = Worksheets("revenue").Cells(3 + k, 18)
Worksheets("pen dressed").Cells(23 + m, 6) = Worksheets("revenue").Cells(3 + k, 19)

Worksheets("pen dressed").Cells(35 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
Worksheets("pen dressed").Cells(35 + m, 2) = Worksheets("revenue").Cells(3 + k, 20)
Worksheets("pen dressed").Cells(35 + m, 3) = Worksheets("revenue").Cells(3 + k, 21)
Worksheets("pen dressed").Cells(35 + m, 4) = Worksheets("revenue").Cells(3 + k, 22)
Worksheets("pen dressed").Cells(35 + m, 5) = Worksheets("revenue").Cells(3 + k, 23)

Worksheets("pen dressed").Cells(47 + m, 1) = Worksheets("revenue").Cells(3 + k, 8)
Worksheets("pen dressed").Cells(47 + m, 2) = Worksheets("revenue").Cells(3 + k, 24)
Worksheets("pen dressed").Cells(47 + m, 3) = Worksheets("revenue").Cells(3 + k, 25)
Worksheets("pen dressed").Cells(47 + m, 4) = Worksheets("revenue").Cells(3 + k, 26)
 m = m + 1
 End If
 k = k + 1
Loop
End If

Calculate
End Sub
Sub growth(k, i, frmsize, grwthint)
 If i = 1 Then
  ' body weight (kg)
  bw = Cells(19 + k, 1) / 2.205
  ' mean feeding weight (kg) - assumes a 3 lb gain on 1st day - half of that is
  ' used in the analysis
  mfw = bw + (1.5 / 2.205)
 ElseIf i > 1 Then
  ' body weight (kg) is the growth model estimate
  bw = Cells(19 + k, 3) / 2.205
  ' mean feeding weight (kg) - half of the current daily gain
  mfw = bw + ((Cells(19 + k, 18) / 2) / 2.205)
 End If

  ' net energy for maintanence requirement [NRC; modification of Fox & Black]
  nem = 0.077 * (mfw ^ 0.75)
  ' DM intake (kg & lb) - Gill's Intake Parameters
  stwt = Cells(19 + k, 1)
   intfac = Application.WorksheetFunction.HLookup(stwt, Range("k6:o7"), 2)
   factor = Range("c7") + (Range("d7") * intfac) + (Cells(19 + k, 1) / 2.205) / 4545
   intake = Range("c6") * (factor * (bw ^ 0.75) - (Range("d6") * bw - 2.5) ^ 2)

  If Range("c10") = 1 Or Range("c10") = 3 Then
   intake = intake * (1 + Cells(19 + k, 29))
  End If

  intakelb = intake * 2.205

  ' daily gain (lb) [NRC with supplemental info from Fox & Black and An Sci FLCALC]
  ffm = nem / Range("d1")
   nefg = (intake - ffm) * Range("d2")
   mfwlb = mfw * 2.205
```

```
'   If frmsize = 1 Then
    'original intercept=65.571
    Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'     ElseIf frmsize = 2 Then
'     'original intercept=58.731
'      Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'       ElseIf frmsize = 3 Then
'       'original intercept=52.571
'        Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'         ElseIf frmsize = 4 Then
'         'original intercept=45.656
'          Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'           ElseIf frmsize = 5 Then
'           'original intercept=40.982
'            Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'             ElseIf frmsize = 6 Then
'             'original intercept=52.571
'              Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'   End If

  If Range("c10") = 2 Or Range("c10") = 3 Then
   Cells(19 + k, 18) = Cells(19 + k, 18) * (1 + Cells(19 + k, 30))
  End If

' previous weight used for feed conversion calculation
 pwght = Cells(19 + k, 3)
' current weight
 If i = 1 Then
  Cells(19 + k, 3) = Cells(19 + k, 1) + Cells(19 + k, 18)
   ElseIf i > 1 Then
    Cells(19 + k, 3) = Cells(19 + k, 3) + Cells(19 + k, 18)
 End If

' feed conversion
 If i = 1 Then
  Cells(19 + k, 19) = intakelb / (Cells(19 + k, 3) - Cells(19 + k, 1))
   Else: Cells(19 + k, 19) = intakelb / (Cells(19 + k, 3) - pwght)
 End If

' feed cost for current DOF
 cfc = intakelb * Range("j3")

' accumulated feed costs
 If i = 1 Then
  Cells(19 + k, 5) = cfc
   Else: Cells(19 + k, 5) = Cells(19 + k, 5) + cfc
 End If

If Cells(19 + k, 1) >= 700 And Cells(19 + k, 1) < 800 Then
 pp = Range("i1")
  ElseIf Cells(19 + k, 1) >= 400 And Cells(19 + k, 1) < 600 Then
   pp = Range("i1") * 1.104
    ElseIf Cells(19 + k, 1) >= 600 And Cells(19 + k, 1) < 700 Then
     pp = Range("i1") * 1.045
      ElseIf Cells(19 + k, 1) >= 800 And Cells(19 + k, 1) < 900 Then
       pp = Range("i1") * 0.9202
        ElseIf Cells(19 + k, 1) >= 900 Then
         pp = Range("i1") * 0.8886
End If

 purchcosts = ((Cells(19 + k, 1) / 100) * pp)
 cattleint = (0.75 * (purchcosts + Range("i8"))) * Range("i7") * (i / 360)
 deathloss = (purchcosts + Range("i10")) * Range("i9")
 othercosts = Range("i8") + Range("i10") + Range("i11") + Range("i12") + _
  (Range("i13") * i)
 operatingint = (0.75 * (Range("i10") + Range("i11") + Range("i12") + (Range("i13") * i) + _
  Cells(19 + k, 5))) * Range("i7") * (i / 720)

 Cells(19 + k, 6) = purchcosts + cattleint + deathloss + othercosts + _
  operatingint + Cells(19 + k, 5)
```

```
End Sub
Sub revenue(i, k, pcnt, begin, finish, p, d, m, cnt)
' calculates probabilities of yield and quality grades for 1998 cattle
 drspcnt = (59.244357 + (0.0029927 * Cells(19 + k, 3))) / 100

  iy1 = 82.0939
  iy2 = 84.8634
  iy3 = 87.4282
  iy4 = 89.9601
  ygv1 = -8.7489
  ygv2 = -2.3111
   var1 = Log(Cells(19 + k, 3))
   var2 = Log(i ^ 2)
 ufy1 = iy1 + (ygv1 * var1) + (ygv2 * var2)
 ufy2 = iy2 + (ygv1 * var1) + (ygv2 * var2)
 ufy3 = iy3 + (ygv1 * var1) + (ygv2 * var2)
 ufy4 = iy4 + (ygv1 * var1) + (ygv2 * var2)

 Cells(19 + k, 7) = Exp(ufy1) / (1 + Exp(ufy1))
 Cells(19 + k, 8) = (Exp(ufy2) / (1 + Exp(ufy2))) - _
  (Exp(ufy1) / (1 + Exp(ufy1)))
 Cells(19 + k, 9) = (Exp(ufy3) / (1 + Exp(ufy3))) - _
  (Exp(ufy2) / (1 + Exp(ufy2)))
 Cells(19 + k, 10) = (Exp(ufy4) / (1 + Exp(ufy4))) - _
  (Exp(ufy3) / (1 + Exp(ufy3)))
 Cells(19 + k, 11) = 1 - (Exp(ufy4) / (1 + Exp(ufy4)))

  iq1 = -35.9428
  iq2 = -30.6281
  iq3 = -27.9
  qgva = 2.7558
  qgvb = 1.148
   vara = Log(Cells(19 + k, 3))
   varb = Log(i ^ 2)
 ufq1 = iq1 + (qgva * vara) + (qgvb * varb)
 ufq2 = iq2 + (qgva * vara) + (qgvb * varb)
 ufq3 = iq3 + (qgva * vara) + (qgvb * varb)

 Cells(19 + k, 12) = Exp(ufq1) / (1 + Exp(ufq1))
 Cells(19 + k, 13) = (Exp(ufq2) / (1 + Exp(ufq2))) - _
  (Exp(ufq1) / (1 + Exp(ufq1)))
 Cells(19 + k, 14) = (Exp(ufq3) / (1 + Exp(ufq3))) - _
  (Exp(ufq2) / (1 + Exp(ufq2)))
 Cells(19 + k, 15) = 1 - (Exp(ufq3) / (1 + Exp(ufq3)))

py1 = Cells(19 + k, 7)
py2 = Cells(19 + k, 8)
py3 = Cells(19 + k, 9)
py4 = Cells(19 + k, 10)
py5 = Cells(19 + k, 11)

yg1 = 0
yg2 = 0
yg3 = 0
yg4 = 0
yg5 = 0

 If Cells(19 + k, 20) <= py1 Then
  yg1 = 1
   ElseIf Cells(19 + k, 20) > py1 And Cells(19 + k, 20) <= (py1 + py2) Then
    yg2 = 1
     ElseIf Cells(19 + k, 20) > (py1 + py2) And Cells(19 + k, 20) <= (py1 + py2 + py3) Then
      yg3 = 1
       ElseIf Cells(19 + k, 20) > (py1 + py2 + py3) And Cells(19 + k, 20) <= (py1 + py2 + py3 + py4) Then
        yg4 = 1
         ElseIf Cells(19 + k, 20) > (py1 + py2 + py3 + py4) Then
          yg5 = 1
 End If
```

```
pq1 = Cells(19 + k, 12)
pq2 = Cells(19 + k, 13)
pq3 = Cells(19 + k, 14)
pq4 = Cells(19 + k, 15)

qg1 = 0
qg2 = 0
qg3 = 0
qg4 = 0

 If Cells(19 + k, 21) <= pq4 Then
  qg4 = 1
   ElseIf Cells(19 + k, 21) > pq4 And Cells(19 + k, 21) <= (pq4 + pq3) Then
    qg3 = 1
     ElseIf Cells(19 + k, 21) > (pq4 + pq3) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2) Then
      qg2 = 1
       ElseIf Cells(19 + k, 21) > (pq4 + pq3 + pq2) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2 + pq1) Then
        qg1 = 1
 End If

prime = Worksheets("revenue").Range("d12")
selct = Worksheets("revenue").Range("d13")
stndrd = Worksheets("revenue").Range("d14")
yield1 = Worksheets("revenue").Range("d16")
yield2 = Worksheets("revenue").Range("d17")
yield4 = Worksheets("revenue").Range("d18")
yield5 = Worksheets("revenue").Range("d19")

' net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 22) = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5) + _
  (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd)
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 22) = (Cells(19 + k, 7) * yield1) + _
   (Cells(19 + k, 8) * yield2) + _
   (Cells(19 + k, 10) * yield4) + _
   (Cells(19 + k, 11) * yield5) + _
   (Cells(19 + k, 12) * prime) + _
   (Cells(19 + k, 14) * selct) + _
   (Cells(19 + k, 15) * stndrd)
End If

' yield net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 23) = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5)
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 23) = (Cells(19 + k, 7) * yield1) + _
   (Cells(19 + k, 8) * yield2) + _
   (Cells(19 + k, 10) * yield4) + _
   (Cells(19 + k, 11) * yield5)
End If

' quality net premiums
If Range("n9") = 2 Then
 Cells(19 + k, 24) = (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd)
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 24) = (Cells(19 + k, 12) * prime) + _
   (Cells(19 + k, 14) * selct) + _
   (Cells(19 + k, 15) * stndrd)
End If
```

```
' dressed profits
Cells(19 + k, 25) = (Worksheets("revenue").Range("d24") * ((Cells(19 + k, 3) * drspcnt) / 100)) - _
  Cells(19 + k, 6)

' cash profits
Cells(19 + k, 27) = (Worksheets("revenue").Range("d25") * (Cells(19 + k, 3) / 100)) - Cells(19 + k, 6)

" calculates the expected grid price and profit
' If (Cells(19 + k, 3) * drspcnt) < Worksheets("revenue").Range("a21") Then
'  light = Worksheets("revenue").Range("d21")
'  heavy = 0
'  ElseIf (Cells(19 + k, 3) * drspcnt) > Worksheets("revenue").Range("a22") Then
'    light = 0
'    heavy = Worksheets("revenue").Range("d22")
'     Else
'      light = 0
'      heavy = 0
' End If
'
' If light > 0 Then
' Cells(19 + k, 16) = 1
'  Else: Cells(19 + k, 16) = 0
' End If
'
' If heavy > 0 Then
' Cells(19 + k, 17) = 1
'  Else: Cells(19 + k, 17) = 0
' End If

ldiff = ((Worksheets("revenue").Range("a21") / 0.63) - Cells(19 + k, 3)) / Range("c9")
hdiff = ((Worksheets("revenue").Range("a22") / 0.63) - Cells(19 + k, 3)) / Range("c9")
 light = WorksheetFunction.NormSDist(ldiff) * Worksheets("revenue").Range("d21")
 heavy = (1 - WorksheetFunction.NormSDist(hdiff)) * Worksheets("revenue").Range("d22")
  Cells(19 + k, 16) = light
  Cells(19 + k, 17) = heavy

If Range("n9") = 2 Then
 Cells(19 + k, 2) = Worksheets("revenue").Range("d9") + _
  (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5) + _
  (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd) + light + heavy
 ElseIf Range("n9") = 1 Then
  Cells(19 + k, 2) = Worksheets("revenue").Range("d9") + _
   (Cells(19 + k, 7) * yield1) + _
   (Cells(19 + k, 8) * yield2) + _
   (Cells(19 + k, 10) * yield4) + _
   (Cells(19 + k, 11) * yield5) + _
   (Cells(19 + k, 12) * prime) + _
   (Cells(19 + k, 14) * selct) + _
   (Cells(19 + k, 15) * stndrd) + light + heavy
End If

 Cells(19 + k, 4) = Cells(19 + k, 2) * ((Cells(19 + k, 3) * drspcnt) / 100)

 Cells(19 + k, 26) = Cells(19 + k, 4) - Cells(19 + k, 6)

If i >= begin And i <= finish Then
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 8) = d
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 9) = i
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 10) = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 2), Cells(19 + (m - 1) + cnt, 2)))
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 11) = _
  Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 4), Cells(19 + (m - 1) + cnt, 4)))
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 12) = _
  Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 6), Cells(19 + (m - 1) + cnt, 6)))
```

```
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 13) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 11) - _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 12)
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 14) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 13) / cnt
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 24) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 16), Cells(19 + (m - 1) + cnt, 16)))
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 25) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 17), Cells(19 + (m - 1) + cnt, 17)))
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 26) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 3), Cells(19 + (m - 1) + cnt, 3)))


If Range("o11") = 1 Or Range("o11") = 3 Then
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 29) = _
 Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 27), Cells(19 + (m - 1) + cnt, 27)))
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 28) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 29) + _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 12)
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 30) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 29) / cnt
End If

If Range("o11") = 2 Or Range("o11") = 3 Then
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 33) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 25), Cells(19 + (m - 1) + cnt, 25)))
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 32) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 33) + _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 12)
Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 34) = _
 Worksheets("revenue").Cells(3 + (pcnt * 30) + (i - begin) + p, 33) / cnt
End If
End If

Worksheets("pen grid").Cells(10 + pcnt, 1) = d
Worksheets("pen grid").Cells(10 + pcnt, 2) = cnt
Worksheets("pen cash").Cells(10 + pcnt, 1) = d
Worksheets("pen cash").Cells(10 + pcnt, 2) = cnt
Worksheets("pen dressed").Cells(10 + pcnt, 1) = d
Worksheets("pen dressed").Cells(10 + pcnt, 2) = cnt

End Sub

Sub info(d, i, m, cnt, prev, pcost, ptwght)
Worksheets("pen info").Range("a1") = Worksheets("revenue").Cells(8, 4) & " - Pen Level"
Worksheets("pen info").Cells(2, 1 + (9 * (d - 4))) = "Pen " & d
Worksheets("pen info").Cells(3 + i, 1 + (9 * (d - 4))) = i
Worksheets("pen info").Cells(3 + i, 2 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 22), Cells(19 + (m - 1) + cnt, 22)))
Worksheets("pen info").Cells(3 + i, 3 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 23), Cells(19 + (m - 1) + cnt, 23)))
Worksheets("pen info").Cells(3 + i, 4 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 24), Cells(19 + (m - 1) + cnt, 24)))
Worksheets("pen info").Cells(3 + i, 5 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 25), Cells(19 + (m - 1) + cnt, 25)))
Worksheets("pen info").Cells(3 + i, 6 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 26), Cells(19 + (m - 1) + cnt, 26)))
Worksheets("pen info").Cells(3 + i, 7 + (9 * (d - 4))) = _
 Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19 + m, 27), Cells(19 + (m - 1) + cnt, 27)))

If i > 1 Then
Worksheets("pen info").Cells(3 + i, 8 + (9 * (d - 4))) = _
 (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 4), Cells(19 + (m - 1) + cnt, 4))) - prev) _
   / (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 3), Cells(19 + (m - 1) + cnt, 3))) - ptwght)
Worksheets("pen info").Cells(3 + i, 9 + (9 * (d - 4))) = _
 (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 6), Cells(19 + (m - 1) + cnt, 6))) _
   - pcost) / (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 3), Cells(19 + (m - 1) + cnt, 3))) - ptwght)

Worksheets("changes").Cells(2, 1 + (4 * (d - 4))) = "Pen " & d
Worksheets("changes").Cells(2 + i, 1 + (4 * (d - 4))) = i
```

```
Worksheets("changes").Cells(2 + i, 2 + (4 * (d - 4))) = _
 (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 4), Cells(19 + (m - 1) + cnt, 4))) - prev)
Worksheets("changes").Cells(2 + i, 3 + (4 * (d - 4))) = _
 (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 6), Cells(19 + (m - 1) + cnt, 6))) - pcost)
Worksheets("changes").Cells(2 + i, 4 + (4 * (d - 4))) = _
 (WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19 + m, 3), Cells(19 + (m - 1) + cnt, 3))) - ptwght)
End If

End Sub
```

Appendix D

Visual Basic Program for the Individual Growth Model

The following is the Visual Basic code used to grow cattle and sell animals on an individual basis when their profit is maximized.

```
Sub Individual()
Worksheets("growth").Activate
 Range("b19:ae1000").ClearContents
Worksheets("Indiv").Range("d3:d9").ClearContents
Worksheets("Indiv").Range("a14:l14").ClearContents
Worksheets("Indiv").Range("a18:e18").ClearContents
Worksheets("Indiv").Range("a23:d23").ClearContents
Worksheets("Indiv").Range("a28:c28").ClearContents

Calculate

dof = Range("d13")
frmsize = Range("c5")
grwthint = Range("c8")

cnt = 0
 Do Until Cells(19 + cnt, 1) = Empty
  If Range("n9") = 2 Then
   Cells(19 + cnt, 21) = Rnd
   Cells(19 + cnt, 22) = Rnd
  End If
  cnt = cnt + 1
 Loop

k = 0
Do Until Cells(19 + k, 1) = Empty
 For i = 1 To dof
  Range("d14") = i
  Range("d15") = k + 1

' calculations for specified number of days on feed
 If i = 1 Then
  ' body weight (kg)
  bw = Cells(19 + k, 1) / 2.205
  ' mean feeding weight (kg) - assumes a 3 lb gain on 1st day - half of that is
  ' used in the analysis
  mfw = bw + (1.5 / 2.205)
  ElseIf i > 1 Then
  ' body weight (kg) is the growth model estimate
  bw = Cells(19 + k, 4) / 2.205
  ' mean feeding weight (kg) - half of the current daily gain
  mfw = bw + ((Cells(19 + k, 19) / 2) / 2.205)
 End If

  ' net energy for maintanence requirement [NRC; modification of Fox & Black]
  nem = 0.077 * (mfw ^ 0.75)
  ' DM intake (kg) [intake function used in BeefGain program - considers yearlings only]
  stwt = Cells(19 + k, 1)
   intfac = Application.WorksheetFunction.HLookup(stwt, Range("k6:o7"), 2)
   factor = Range("c7") + (Range("d7") * intfac) + (Cells(19 + k, 1) / 2.205) / 4545
   intake = Range("c6") * (factor * (bw ^ 0.75) - (Range("d6") * bw - 2.5) ^ 2)

  If Range("c10") = 1 Or Range("c10") = 3 Then
```

```
  intake = intake * (1 + Cells(19 + k, 29))
  End If

  intakelb = intake * 2.205

 ' daily gain (lb) [NRC with supplemental info from Fox & Black and An Sci FLCALC]
  ffm = nem / Range("d1")
   nefg = (intake - ffm) * Range("d2")
   mfwlb = mfw * 2.205
'    If frmsize = 1 Then
    'original intercept=65.571
    c19 = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'     ElseIf frmsize = 2 Then
'     'original intercept=58.731
'      Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'       ElseIf frmsize = 3 Then
'       'original intercept=52.571
'        Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)
'         ElseIf frmsize = 4 Then
'         'original intercept=45.656
'          Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'           ElseIf frmsize = 5 Then
'           'original intercept=40.982
'            Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6702) * (nefg ^ 0.8936)
'             ElseIf frmsize = 6 Then
'             'original intercept=52.571
'              Cells(19 + k, 18) = grwthint * (mfwlb ^ -0.6837) * (nefg ^ 0.9116)

  If Range("c10") = 2 Or Range("c10") = 3 Then
   c19 = c19 * (1 + Cells(19 + k, 30))
  End If

' previous weight used for feed conversion calculation
 pwght = Cells(19 + k, 4)
' current weight
 If i = 1 Then
 c4 = Cells(19 + k, 1) + c19
  ElseIf i > 1 Then
   c4 = c4 + c19
 End If

' feed conversion
 If i = 1 Then
 c20 = intakelb / (c4 - Cells(19 + k, 1))
  Else: c20 = intakelb / (c4 - pwght)
 End If

' feed cost for current DOF
 cfc = intakelb * Range("j3")

' accumulated feed costs
 If i = 1 Then
  c6 = cfc
  Else: c6 = c6 + cfc
 End If

If Cells(19 + k, 1) >= 700 And Cells(19 + k, 1) < 800 Then
 pp = Range("i1")
  ElseIf Cells(19 + k, 1) >= 400 And Cells(19 + k, 1) < 600 Then
   pp = Range("i1") * 1.104
   ElseIf Cells(19 + k, 1) >= 600 And Cells(19 + k, 1) < 700 Then
    pp = Range("i1") * 1.045
    ElseIf Cells(19 + k, 1) >= 800 And Cells(19 + k, 1) < 900 Then
     pp = Range("i1") * 0.9202
      ElseIf Cells(19 + k, 1) >= 900 Then
       pp = Range("i1") * 0.8886
End If

 purchcosts = ((Cells(19 + k, 1) / 100) * pp)
 cattleint = (0.75 * (purchcosts + Range("i8"))) * Range("i7") * (i / 360)
```

```
deathloss = (purchcosts + Range("i10")) * Range("i9")
othercosts = Range("i8") + Range("i10") + Range("i11") + Range("i12") + _
 (Range("i13") * i)
operatingint = (0.75 * (Range("i10") + Range("i11") + Range("i12") + (Range("i13") * i) + _
 c6)) * Range("i7") * (i / 720)

c7 = purchcosts + cattleint + deathloss + othercosts + _
 operatingint + c6

' calculates probabilities of yield and quality grades for 1998 cattle
drspcnt = (59.244357 + (0.0029927 * c4)) / 100

 iy1 = 82.0939
 iy2 = 84.8634
 iy3 = 87.4282
 iy4 = 89.9601
 ygv1 = -8.7489
 ygv2 = -2.3111
  var1 = Log(c4)
  var2 = Log(i ^ 2)
 ufy1 = iy1 + (ygv1 * var1) + (ygv2 * var2)
 ufy2 = iy2 + (ygv1 * var1) + (ygv2 * var2)
 ufy3 = iy3 + (ygv1 * var1) + (ygv2 * var2)
 ufy4 = iy4 + (ygv1 * var1) + (ygv2 * var2)

 c8 = Exp(ufy1) / (1 + Exp(ufy1))
 c9 = (Exp(ufy2) / (1 + Exp(ufy2))) - _
  (Exp(ufy1) / (1 + Exp(ufy1)))
 c10 = (Exp(ufy3) / (1 + Exp(ufy3))) - _
  (Exp(ufy2) / (1 + Exp(ufy2)))
 c11 = (Exp(ufy4) / (1 + Exp(ufy4))) - _
  (Exp(ufy3) / (1 + Exp(ufy3)))
 c12 = 1 - (Exp(ufy4) / (1 + Exp(ufy4)))

 iq1 = -35.9428
 iq2 = -30.6281
 iq3 = -27.9
 qgva = 2.7558
 qgvb = 1.148
  vara = Log(c4)
  varb = Log(i ^ 2)
 ufq1 = iq1 + (qgva * vara) + (qgvb * varb)
 ufq2 = iq2 + (qgva * vara) + (qgvb * varb)
 ufq3 = iq3 + (qgva * vara) + (qgvb * varb)

 c13 = Exp(ufq1) / (1 + Exp(ufq1))
 c14 = (Exp(ufq2) / (1 + Exp(ufq2))) - _
  (Exp(ufq1) / (1 + Exp(ufq1)))
 c15 = (Exp(ufq3) / (1 + Exp(ufq3))) - _
  (Exp(ufq2) / (1 + Exp(ufq2)))
 c16 = 1 - (Exp(ufq3) / (1 + Exp(ufq3)))

py1 = c8
py2 = c9
py3 = c10
py4 = c11
py5 = c12

yg1 = 0
yg2 = 0
yg3 = 0
yg4 = 0
yg5 = 0

 If Cells(19 + k, 20) <= py1 Then
  yg1 = 1
   ElseIf Cells(19 + k, 20) > py1 And Cells(19 + k, 20) <= (py1 + py2) Then
    yg2 = 1
     ElseIf Cells(19 + k, 20) > (py1 + py2) And Cells(19 + k, 20) <= (py1 + py2 + py3) Then
      yg3 = 1
```

```
      ElseIf Cells(19 + k, 20) > (py1 + py2 + py3) And Cells(19 + k, 20) <= (py1 + py2 + py3 + py4) Then
       yg4 = 1
        ElseIf Cells(19 + k, 20) > (py1 + py2 + py3 + py4) Then
         yg5 = 1
 End If

 pq1 = c13
 pq2 = c14
 pq3 = c15
 pq4 = c16

 qg1 = 0
 qg2 = 0
 qg3 = 0
 qg4 = 0

 If Cells(19 + k, 21) <= pq4 Then
  qg4 = 1
   ElseIf Cells(19 + k, 21) > pq4 And Cells(19 + k, 21) <= (pq4 + pq3) Then
    qg3 = 1
     ElseIf Cells(19 + k, 21) > (pq4 + pq3) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2) Then
      qg2 = 1
       ElseIf Cells(19 + k, 21) > (pq4 + pq3 + pq2) And Cells(19 + k, 21) <= (pq4 + pq3 + pq2 + pq1) Then
        qg1 = 1
 End If

prime = Worksheets("grid").Range("d12")
selct = Worksheets("grid").Range("d13")
stndrd = Worksheets("grid").Range("d14")
yield1 = Worksheets("grid").Range("d16")
yield2 = Worksheets("grid").Range("d17")
yield4 = Worksheets("grid").Range("d18")
yield5 = Worksheets("grid").Range("d19")

' net premiums
If Range("n9") = 2 Then
 c23 = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5) + _
  (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd)
 ElseIf Range("n9") = 1 Then
  c23 = (c8 * yield1) + _
   (c9 * yield2) + _
   (c11 * yield4) + _
   (c12 * yield5) + _
   (c13 * prime) + _
   (c15 * selct) + _
   (c16 * stndrd)

End If

' yield net premiums
If Range("n9") = 2 Then
 c24 = (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5)
 ElseIf Range("n9") = 1 Then
  c24 = (c8 * yield1) + _
   (c9 * yield2) + _
   (c11 * yield4) + _
   (c12 * yield5)
End If

' quality net premiums
If Range("n9") = 2 Then
 c25 = (qg1 * prime) + _
```

```
 (qg3 * selct) + _
 (qg4 * stndrd)
ElseIf Range("n9") = 1 Then
 c25 = (c13 * prime) + _
  (c15 * selct) + _
  (c16 * stndrd)
End If

' dressed profits
c26 = (Worksheets("grid").Range("d24") * ((c4 * drspcnt) / 100)) - _
  c7

' cash profits
c28 = (Worksheets("grid").Range("d25") * (c4 / 100)) - c7

'' calculates the expected grid price and profit
' If (c4 * drspcnt) < Worksheets("grid").Range("a21") Then
'  light = Worksheets("grid").Range("d21")
'  heavy = 0
'   ElseIf (c4 * drspcnt) > Worksheets("grid").Range("a22") Then
'    light = 0
'    heavy = Worksheets("grid").Range("d22")
'     Else
'      light = 0
'      heavy = 0
' End If
'
' If light < 0 Then
'  c17 = 1
'  Else: c17 = 0
' End If
'
' If heavy < 0 Then
'  c18 = 1
'  Else: c18 = 0
' End If

ldiff = ((Worksheets("grid").Range("a21") / 0.63) - c4) / Range("c9")
hdiff = ((Worksheets("grid").Range("a22") / 0.63) - c4) / Range("c9")
 light = WorksheetFunction.NormSDist(ldiff) * Worksheets("grid").Range("d21")
 heavy = (1 - WorksheetFunction.NormSDist(hdiff)) * Worksheets("grid").Range("d22")
 c17 = light
 c18 = heavy

If Range("n9") = 2 Then
 c3 = Worksheets("grid").Range("d9") + _
  (yg1 * yield1) + _
  (yg2 * yield2) + _
  (yg4 * yield4) + _
  (yg5 * yield5) + _
  (qg1 * prime) + _
  (qg3 * selct) + _
  (qg4 * stndrd) + light + heavy
 ElseIf Range("n9") = 1 Then
  c3 = Worksheets("grid").Range("d9") + _
   (c8 * yield1) + _
   (c9 * yield2) + _
   (c11 * yield4) + _
   (c12 * yield5) + _
   (c13 * prime) + _
   (c15 * selct) + _
   (c16 * stndrd) + light + heavy
End If

 c5 = c3 * ((c4 * drspcnt) / 100)

 c27 = c5 - c7
 If i = 1 Then
  Cells(19 + k, 4) = c4
  Cells(19 + k, 19) = c19
```

```
 Cells(19 + k, 27) = c27
End If

If i > 1 And c27 > Cells(19 + k, 27) Then
 Cells(19 + k, 3) = c3
 Cells(19 + k, 4) = c4
 Cells(19 + k, 5) = c5
 Cells(19 + k, 6) = c6
 Cells(19 + k, 7) = c7
 Cells(19 + k, 8) = c8
 Cells(19 + k, 9) = c9
 Cells(19 + k, 10) = c10
 Cells(19 + k, 11) = c11
 Cells(19 + k, 12) = c12
 Cells(19 + k, 13) = c13
 Cells(19 + k, 14) = c14
 Cells(19 + k, 15) = c15
 Cells(19 + k, 16) = c16
 Cells(19 + k, 17) = c17
 Cells(19 + k, 18) = c18
 Cells(19 + k, 19) = c19
 Cells(19 + k, 20) = c20
 Cells(19 + k, 23) = c23
 Cells(19 + k, 24) = c24
 Cells(19 + k, 25) = c25
 Cells(19 + k, 26) = c26
 Cells(19 + k, 27) = c27
 Cells(19 + k, 28) = c28
 ElseIf i > 1 Then
  Cells(19 + k, 2) = i - 1
  GoTo over
 End If

Calculate

Next i
over:
 k = k + 1
Loop

  Worksheets("Indiv").Range("a1") = Worksheets("grid").Cells(8, 4) & " - Individual Cattle - " & Range("m2")
  Worksheets("Indiv").Range("d3") = cnt
  Worksheets("Indiv").Range("d4") = Range("i1")
  Worksheets("Indiv").Range("d5") = Range("i2")
  Worksheets("Indiv").Range("d6") = Range("d3")
  Worksheets("Indiv").Range("d7") = Worksheets("grid").Range("d9")
  Worksheets("Indiv").Range("d8") = Worksheets("grid").Range("d25")
  Worksheets("Indiv").Range("d9") = Worksheets("grid").Range("d24")

  Worksheets("Indiv").Range("a14") = _
   Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 2), Cells(19 + cnt - 1, 2)))
  Worksheets("Indiv").Range("b14") = _
   Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 3), Cells(19 + cnt - 1, 3)))
  Worksheets("Indiv").Range("c14") = _
   Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19, 5), Cells(19 + cnt - 1, 5)))
  Worksheets("Indiv").Range("d14") = _
   Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19, 7), Cells(19 + cnt - 1, 7)))
  Worksheets("Indiv").Range("e14") = Worksheets("Indiv").Range("c14") - Worksheets("Indiv").Range("d14")
  Worksheets("Indiv").Range("f14") = Worksheets("Indiv").Range("e14") / cnt

  Worksheets("Indiv").Range("h14") = _
   Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19, 28), Cells(19 + cnt - 1, 28)))
  Worksheets("Indiv").Range("i14") = Worksheets("Indiv").Range("h14") / cnt

  Worksheets("Indiv").Range("k14") = _
   Application.WorksheetFunction.Sum(Worksheets("growth").Range(Cells(19, 26), Cells(19 + cnt - 1, 26)))
  Worksheets("Indiv").Range("l14") = Worksheets("Indiv").Range("k14") / cnt

  Worksheets("Indiv").Range("a18") = _
   Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 8), Cells(19 + cnt - 1, 8)))
```

```
 Worksheets("Indiv").Range("b18") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 9), Cells(19 + cnt - 1, 9)))
 Worksheets("Indiv").Range("c18") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 10), Cells(19 + cnt - 1, 10)))
 Worksheets("Indiv").Range("d18") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 11), Cells(19 + cnt - 1, 11)))
 Worksheets("Indiv").Range("e18") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 12), Cells(19 + cnt - 1, 12)))

 Worksheets("Indiv").Range("a23") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 13), Cells(19 + cnt - 1, 13)))
 Worksheets("Indiv").Range("b23") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 14), Cells(19 + cnt - 1, 14)))
 Worksheets("Indiv").Range("c23") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 15), Cells(19 + cnt - 1, 15)))
 Worksheets("Indiv").Range("d23") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 16), Cells(19 + cnt - 1, 16)))

 Worksheets("Indiv").Range("a28") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 17), Cells(19 + cnt - 1, 17)))
 Worksheets("Indiv").Range("b28") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 18), Cells(19 + cnt - 1, 18)))
 Worksheets("Indiv").Range("c28") = _
  Application.WorksheetFunction.Average(Worksheets("growth").Range(Cells(19, 4), Cells(19 + cnt - 1, 4)))
End Sub
```

VITA

Heather C. Greer

Candidate for the Degree of

Doctor of Philosophy

Thesis: VALUE DETERMINANTS, ALTERNATIVE GRID PRICING STRUCTURES, AND SORTING IN A VALUE BASED CATTLE MARKETING SYSTEM

Major Field: Agricultural Economics

Biographical:

Education: Received a Bachelor of Science degree in Agricultural Economics with an emphasis on Statistics from Oklahoma State University, Stillwater, OK in May of 1994; completed the requirements for the degree of Master of Science with a major in Agricultural Economics and a specialization in Price Analysis at Washington State University, Pullman, WA in December of 1995; completed the requirements for the degree of Doctor of Philosophy with a major in Agricultural Economics and a specialization in Livestock Marketing at Oklahoma State University, Stillwater, OK in December of 2000.

Professional Experience: Undergraduate Research and Teaching Assistant, Oklahoma State University, August 1992 – May 1994; Graduate Research and Teaching Assistant, Washington State University, August 1994 – December 1995; Financial and Marketing Analyst/Programmer, Foundation Health, February 1996 – August 1997; Graduate Research and Teaching Assistant, Oklahoma State University, August 1997 to August 2000.

Awards: Eugene and Doris Miller Distinguished Graduate Fellowship, Oklahoma State University, July 1998 – August 2000.