EFFECTS OF WINTER WEATHER RISK ON THE PROFITABILITY OF BEEF FEEDLOTS IN NORTH DAKOTA

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ABSTRACT

This study examines the effects of management decisions, animal performance, weather risk, and economic variables on the profitability of the beef feedlot in North Dakota using data from the Dakota Feeder Calf Show and feed trials at North Dakota State University's Carrington Research and Extension Center. The effects of these variables were studied using an ordinary least squares analysis. Results demonstrated that severe cold stress reduced the profits of the feedlot in North Dakota. Results suggest that steers placed during the fall in North Dakota with placement weights > 600 pounds are more profitable to feed than lighter weight steers.

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INTRODUCTION

North Dakota's cattle industry is the third largest contributor to the state's agricultural receipts (USDA-ERS, 2012). The cow-calf sector provides the majority of these receipts with approximately 860,000 calves born in North Dakota each year (USDA-NASS, 2012). A desire to diversify the cattle industry has led to interest in the cattle feeding sector. The potential opening of a beef processing plant in Aberdeen S.D. and another one under consideration in North Dakota (Roesler, 2012) increases the demand for cattle from cattle feeding operations in the Dakotas. The Aberdeen plant at full capacity will be able to process approximately 1,500 head of cattle in one shift, which is approximately 390,000 head per year. By the end of their first year of operation the plant hopes to be operating two shifts six days a week and processing over 1,000,000 head per year (Northern Beef Packers, 2012). In January 2008 feedlots in North Dakota had the capacity to hold 226,000 head of cattle but less than 103,000 head were fed to finish during 2007 (USDA-NASS, 2008), this is only enough to supply the new processing plant for approximately four to seven weeks. To help fill the demand of the new processing plant many of the calves sent to Nebraska and Kansas for finishing will need to stay in North Dakota.

There are many risks in operating a feedlot; such as volatility of cattle and feed prices, animal illness, death loss and weather, Weather is a risk that producers across the country face every day. In North Dakota finishing cattle during the winter poses a risk to profitability of the feedlot operation. Severe cold stress often encountered during the winter in North Dakota has the potential to affect how efficiently cattle perform by increasing feed intake (National Research Council, 1981). Cattle perform most efficiently at temperatures within their thermo-neutral zone, or comfort zone (National Research Council, 1981). The comfort zone is a range of effective ambient temperatures[1]. Within this range the animal's metabolic rate does not need to change to maintain normal body temperature (National Research Council, 1981). North Dakota experiences temperatures below 0°C (32°F) between 180 and 210 days annually and during 35 to 65 of these days temperatures drop below -18°C (0°F) (NPWRC-USGS, 2006). These low temperatures combined with high wind speeds and heavy snowfalls create weather conditions that are outside the thermoneutral zone of feedlot cattle raised in North Dakota.

As cattle increase heat production to maintain body temperature during times of cold stress their feed energy requirements increase, thus adjustments must be made to the energy level of the ration to maintain production levels (National Research Council, 1981). These adjustments to the diet increase feeding costs as higher energy feed ingredients such as corn are more expensive to feed. This increase in high quality feed requirements coupled with the expected decrease in production adds to the concern that the harsh winters of North Dakota will reduce the profitability of the feedlot.

Examining the profitability of feedlots in North Dakota is important in determining the potential of diversifying the beef industry in the state. Producers are risk takers but every producer has some level of risk aversion. Quantifying the effect of weather risk on feedlot profits will help producers determine if the risk that comes with feeding cattle to finish during North Dakota winters are greater than the level of risk they are willing to take on. Hoppe et al. (1997) found that North Dakota born calves placed on feed in the fall and fed a corn based diet in North Dakota had a lower cost of gain than similar calves fed a corn based diet in Kansas by an average of $0.04 per pound of gain due to cheaper feed costs in North Dakota. They also found that average daily gains in North Dakota were approximately 0.25 pounds per head lower than those

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[1] "The temperature of an isothermal environment without appreciable air movement or radiation gain that results in the same heat demand as the environment in question" (National Research Council, 1981)

in Kansas. Despite these lower gains it was noted that calves fed in North Dakota appeared to be as profitable as those fed in Kansas due to the lower feed costs in North Dakota. Indicating that the lower feed costs in North Dakota may make up for the effects of weather risks on feedlot profits. Analyzing management decisions, animal performance, and economic variables along with weather risk during the feeding period provides information on how these factors influence the profitability of the feedlot in North Dakota helping producers determine if the potential cost associated with weather risk is more than the potential profits.

LITERATURE

Previous studies have evaluated factors that affect the profitability of cattle feeding operations to find that input and selling prices, feed conversion rates, and average daily gain had a significant effect on feedlot profitability (Langemeier, Schroeder, and Mintert, 1992; Schroeder, Albright, Langemeier, and Mintert, 1993). Lawrence, Wang, and Loy (1999) studied the effect of cattle placement weights and season of placement on feedlot profitability in addition to the price and performance variables of earlier studies while Belasco et al. (2009) studied the effect of conditioning factors known at time of placement on animal performance variables to simulate profitability risk. Mark and Schroeder (2002) examined the effects of average weather conditions during feeding periods on performance and profitability.

Langemeier, Schroeder, and Mintert (1992) used monthly average cost, profit and performance data from a western Kansas custom feedlot to determine the factors that affected feedlot profits per head between three placement weight groups of steers using an ordinary least squares analysis and coefficients of separate determination. They found that sale prices, feeder prices, corn prices, interest rates, feed conversion, and average daily gain explained approximately 98 percent of profits for the western Kansas feedlot. Input prices and selling price explained the majority of the variation compared to cattle performance measures for the three weight groups.

Schroeder et al. (1993) collected pen level data from two western Kansas custom feedlots and used it to evaluate the effect of feeder and fed prices, corn price, feed conversion, average daily gain, interest rates and selling prices on profits. Schroeder et al.'s (1993) results were similar to Langemeier, Schroeder, and Mintert (1992) explaining approximately 93 to 94% of profits across the three weight groups of steers. Input prices and selling price accounted for slightly less of the feedlot profits when pen level data were used, while cattle performance variables accounted for slightly more of feedlot profits. The sale price and corn price explained less of the variation in profits as placement weights increased using pen level data while feed price, feed conversion, and average daily gain explained more of the variation as placement weight increased.

Lawrence, Wang, and Loy (1999) collected data from feedlots in Midwest states (Illinois, Iowa, Minnesota, Nebraska, and South Dakota) to determine if similar results could be found in different climatic conditions compared to western Kansas. They also added placement weight, season of placement, and facility type to determine how these management decisions impact the profitability of the cattle feeding operation. Lawrence, Wang, and Loy (1999) found that the six original variables used in prior studies explained 69% - 88% of feedlot profits for four weight groups of steers; meaning these six variables explain less of the profit equation in the Midwest study than they had in the Kansas study by Schroeder et al. (1993). Selling price explained the majority of profits for cattle feeding operations across the five Midwest states which is consistent with the western Kansas studies. Consistent with Schroeder et al. (1993) the effect of selling price decreased as placement weight increased. Across the five Midwestern states feeder price had a much smaller effect on profits for the 600-699 pounds weight group compared to the two Kansas studies, feeder prices in the Midwest accounted for only 5% of the explained effects compared to 22% (Langemeier, Schroeder, and Mintert, 1992) and 17% (Schroeder et al., 1993) in the two western Kansas studies. Consistent with Schroeder et al. (1993) the effect of purchase price increased as placement weight increased and the effect of corn price decreased as placement weight increased. Performance variables effect on profitability in the five Midwestern states accounted for approximately 7% to 10.2% of feedlot profits, an increase of approximately

2% to 5% in comparison to the Kansas study done by Schroeder et al. (1993). Lawrence, Wang and Loy (1999) expanded the earlier research to include dummy variables that represented management decisions. They determined that a placement weight of <600 is the most profitable of the four placement weights included in the Midwest study. They also determined that as placement weight increased in the Midwest feedlot profits per head decreased. Season of placement showed little difference ($P > 0.05$) in feedlot profits between winter (December – February) and fall (September-November) placed steers in the Midwest.

Belasco et al. (2009) used data from five feedlots located in Kansas and Nebraska to determine the effect of the independent variables: gender, location, in-weight, and season of placement, on dry matter feed conversion, average daily gain, mortality rates, and veterinary costs per head. The regression of the four independent variables on dry matter feed conversion indicated that fall placed cattle were less efficient at converting feed to pounds of weight gain than cattle placed in the other seasons. The regression of the same independent variables on average daily gain indicated that cattle placed in the summer had a higher rate of gain than cattle placed in any other season it also indicated that cattle placed in the fall had the lowest average daily gain of the four seasons of placement. Mortality rates and veterinary costs per head decrease as placement weight increases.

Mark and Schroeder (2002) used data from two commercial feedlots in southwest Kansas to determine the effect of weather conditions on average daily gain and profitability of commercial feedlots in western Kansas. They determined that the average daily gain for heavy weight steers (>700 lbs) placed in January improved by 0.01 pounds per day with a one degree increase in average temperature over the feeding period. Profits were reduced by $0.15 per head for winter fed cattle when there was a 1% increase in the percent of days with low temperatures and high wind speeds. They also found that precipitation during the first and last three weeks of the feeding period reduced profits by $0.60 to $0.70 per head depending on the placement weight and season of the pen.

Belasco and Cheng (2011) used data from two western Kansas feedlots to determine the nonparametric effect of extreme weather events on feedlot profitability. Extreme weather events were quantified using a cold stress index developed by Oklahoma State University and the U. S. Forestry Service (Oklahoma State University, 2012). The cold stress index uses hourly weather data for temperature and wind speed to calculate the level of cold stress. Belasco and Cheng (2011) averaged the hourly index to determine a daily cold stress level. They then regressed independent variables: number of days in the feeding period with a cold stress level of mild, number of days on feed, gender, location, in-weight, season of placement, and number of days of heat stress on the individual dependent variables average daily gain, feed conversion (lbs feed/lb gain), and mortality rates, to determine the threshold days of cold stress that affects these three performance variables. Results demonstrated that steers placed at 600-700 pounds or greater have a threshold level of 80 to 90 days of mild cold stress before a consistent decrease in average daily gain begins, at this same threshold level of mild cold stress a consistent increase in feed conversion was seen. A profit function was calculated, results showed that as days of mild cold stress increased over 90 days profits per head decreased at a higher rate.

In summary, in past studies the main focus of feedlot profitability research has been to determine how price risk and production variables affect the profitability of the feedlot. However, recently corn prices have risen substantially, which is one of the largest input costs for feedlot operations. To capture this price change, we include feed costs and performance variables since it is assumed producers may switch to cheaper feed alternatives, which inevitably will affect weight gain and other performance indicators. Little research has been done to evaluate how weather risk impacts profitability. Mark and Schroeder (2002) analyzed the effects of environmental conditions of temperature, precipitation, wind speed, and humidity to determine how a one unit change in the feeding period average of these variables between years affected the average daily gains and profit of that feeding period. Recent studies in animal science have developed stress indexes that allow for the combined effects of these environmental conditions to be used to predict their effects on animal performance and profits. Belasco and Cheng (2011) used a cattle cold stress index to evaluate the effects of extreme weather conditions on animal performance and profits. The cold stress index used by Belasco and Cheng (2011) only accounted for temperature and wind speed using a subjective hair coat condition that could not be accurately accounted for in the data. Other factors affecting environmental stress levels in cattle include solar radiation, relative humidity and precipitation. The stress levels calculated in by Belasco and Cheng's (2011) study were calculated as a daily average of the hourly stress level, averages may mask extended periods of extreme stress that could affect the performance of the animal. Also, the level of stress evaluated in their study was a mild level according to the index used. Fall placed cattle in North Dakota are subject to more extreme cold stress during the months of January and February and these extreme conditions can also be seen during the early and later months of the feeding period.

OBJECTIVES

There is potential to diversify the North Dakota cattle industry by expanding into the cattle feeding sector. Hoppe et al. (1997) has shown that North Dakota cattle can be fed at a lower cost of gain in North Dakota than they can be fed in Kansas due to lower feed costs. Even with these lower feed cost there is concern that finishing cattle during the winter in North Dakota poses a risk to the profitability of the feedlot operation due to severe cold stress often encountered during the feeding period.

The objective of this study is to quantify the effect of management decisions, animal performance, weather risk, and economic variables on profitability of fall placed cattle in North Dakota. Secondly, this study will show the change in effects on profitability when the percent of days with severe cold stress are compared to the percent of days without severe cold stress. It will also determine at what point(s) during the feeding period exposure to severe cold stress significantly affects profits.

METHODOLOGY

Feedlot owners are profit maximizers who strive to increase profits subject to cost and production level constraints. It is important for feedlot owners to understand how management decisions, animal performance, economic variables, and weather risk factors affect profits. Assuming a linear relationship between profit and these factors we estimate their impacts on feedlot profit using an ordinary least squares analysis. Equation (1) represents this linear model:

(1) $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_{ik} + u$

where β_0 is the intercept representing the expected value of y when all x_i equal zero, all other β_i in this equation are an estimate representing the change in profits given a one unit change in the variable x_i, x_i represents the independent or explanatory variables, and $u \sim N(0,\sigma^2)$ is the error term.

Ordinary Least Squares (OLS) analysis estimates the parameters of a multiple linear regression model by minimizing the sum of squared residuals or error terms across all observations (Wooldridge, 2003) this is represented by Equation (2):

(2) $\sum_{i=1}^{n} (y_i - \beta_0 - \beta_1 x_{i1} - \beta_2 x_{i2} - \ldots - \beta_k x_{ik})^2$

All estimates are chosen simultaneously and measure the partial effect of the corresponding independent variable (x_i) on the dependent variable (y_i) while holding all other independent variables fixed (Wooldridge, 2003).

DATA

Three types of data were collected for this analysis: feedlot production (animal performance and management), economic (prices), and weather (environmental). Production and economic data from the Dakota Feeder Calf Show (DFCS) at North Dakota State University - Carrington Research and Extension Center (NDSU-CREC) was collected for October placement feedlot steers from fall 2005 to fall 2006 and fall 2008 to fall 2011[2]. In order to capture the effect of weather risk on feedlot profitability, weather data were collected from the North Dakota Agricultural Weather Network (NDAWN) website from the Carrington weather tower that is located approximately one-half mile west of the NDSU-CREC feedlot within the same 640 acre section of land. The following sub-sections will provide a description of the data collected and used for the analysis, summary statistics, and the empirical model.

Feedlot Production Data

Langemeier, Schroeder, and Mintert (1992), Schroeder et al. (1993), and Lawrence, Wang, and Loy (1999) determined that animal performance variables, average daily gain and feed conversion, were statistically significant factors affecting profitability of feedlots in Kansas and the Midwest. Performance data collected from DFCS at NDSU-CREC included dates of placement and slaughter (Table 1), individual weights taken at the DFCS weigh-in at Turtle Lake, ND, individual periodic weights (W_i) taken throughout the feeding period at intervals averaging approximately 32 days and the dates the weights were taken (see Appendix Table A1)[3], pen placement, number of head assigned to each pen at placement, pen level ration weights

[2] Pen level feeding data were not collected for the fall 2007 placements; therefore data from this placement year were not included in this study.

[3] Weights were taken six to seven times throughout the feeding period each year. The difference may be due to a shorter time on feed or a longer number of days experienced between weights taken due to management discretion.

fed per day, total weight of each individual feed contained in in the ration, morbidity data on individual steers that were treated during the feeding period, and mortality rates.

TABLE 1: Dates of Placement/Slaughter and Days on Feed (DOF)

Date In	Beginning DOF	Middle DOF	End DOF	Overall DOF	Date out
10/15/2005	58	56	77[1] 98	191[1] 212	04/21/2006 05/15/2006
10/21/2006	59	56	97	212	05/21/2007
10/18/2008	44	83	70	197	05/06/2009
10/17/2009	62	76	61	199	05/04/2010
10/16/2010	59	59	82	200	05/03/2011
10/15/2011	66	56	77	199	05/01/2012

[1]Steers were sent to slaughter on two separate dates in 2005

Individual weight data collected at the DFCS weigh-in at Turtle Lake, ND were used to calculate the average placement weight of each pen of steers. The pens of steers were then categorized into three weight categories to reflect the management decision made by the feedlot producer by steer placement weight: heavy (H), medium (M), and light (L). This management decision is included to reflect the overall differences in the cost of purchasing and feeding steers placed in different weight groups and the overall differences in animal performance for these weight groups. Heavier weight cattle tend to have a lower value per hundred weight but have a higher purchase price per head, are fed higher energy diets throughout the steer's time on feed, and generally reach market weights in fewer days on feed than lighter weight cattle. The heavy (H) weight cattle represents cattle placed on feed that have an initial average pen weight of ≥700 pounds, medium (M) represents cattle placed on feed at an initial average pen weight of 600-699 pounds, and light (L) represents cattle placed on feed at an initial average pen weight of 500-599 pounds. The steers in this study were all weaned steers that are less than one year of age at the time of placement. Lawrence, Wang, and Loy (1999) determined that as steer placement weights increased the effect on profit became more negative when compared to steers placed at less than

600 pounds, giving reason to believe that the less than 600 pounds group are more profitable to feed in the Midwest. We expect to see a negative effect on profits as placement weight increases.

TABLE 2: Description of Management Decision Parameters

Variable	Description	Expected Outcome
Heavy (H)	Pens with an average initial weight of ≥700 pounds	(-) as initial size/age of the steers increases the overall cost of placement increases thus reducing profits
Medium (M)	Pens with an average initial weight of 600-699 pounds	(-) as initial size/age of the steers increases the overall cost of placement increases thus reducing profits
Light (L)	Pens with an average initial weight of 500-599 pounds	This will be the variable the other weight groups are compared to it will not be included in the regression.

Animal performance in a feedlot operation is measured by calculating the average daily gain (ADG) and the feed intake of the cattle. These two variables reflect the effects of animal performance on feed costs which directly impact profits. In this study we have chosen to look at these performance variables during three different segments of the feeding period. The first segment is the beginning (BEG) segment. It is during this period that the lighter weight steers are experiencing compensatory gains[4] from the increase in high energy feeds in their diet. The second and third segments are called the middle (MID) and end (END) segments. As cattle grow the proportion of growth due to lean muscle growth and fat growth changes, as live weight increases, the proportion of weight gained due to fat growth increases (Field, 2007). More feed is needed to produce fat than lean muscle, thus efficiency of cattle begins to taper off as they grow (Field, 2007). Also, during each of these segments cattle are exposed to the climate for the individuals season: fall, winter, and spring. These segments have been broken out to reflect the

[4] "A faster than normal rate of gain following a period of restricted gain" (Field, 2007).

difference in the biological changes in the growth of the steer and the effects of severe cold stress on profits during each of these seasons. The data included in each segment are determined from the dates that periodic individual weights (W_i) were taken during the feeding periods. The BEG segment is based on the data from the dates between initial placement weight and W_2, the MID segment is based on the data from the dates after W_2 to W_4, and the END segment is based on the data from the dates after W_4 to slaughter. Weights were taken throughout each period at intervals averaging approximately 32 days (see Appendix table A1).

Beginning segment average daily gain (BEGADG), middle segment average daily gain (MIDADG) and ending segment average daily gain (ENDADG) were calculated using total weight gained by the pen over the feeding segment (GAIN) and dividing it by the number of days on feed (DOF) during the segment, then dividing that by the number of head (HD) in the pen at the end of the segment to get average daily gain per head.

(3) ADG = (GAIN/DOF)/HD

Beginning segment feed intake (BEGIT), middle segment feed intake (MIDIT) and ending segment feed intake (ENDIT) were calculated using total feed (FEED) fed to the pen during the segment and dividing it by the number of days on feed (DOF) during the segment, then dividing that by the number of head (HD) in the pen at the end of the segment to get average daily feed intake per head.

(4) IT = (FEED/DOF)/HD

As ADG increases we expect to see a positive effect on profits, the more weight the steer gains per day the more overall weight he will gain during the finishing period. This increase in weight is expected to increase the total revenue received. As IT increases we expect to see a negative effect on profits, with every addition pound of feed a steer consumes per day an increase in feed costs which increases total cost thus reducing profits.

TABLE 3: Description of Animal Performance Parameters

Beginning Average Daily Gain (BEGADG)	Average pounds of gain per day per head during the first 44-66 days on feed	(+) increase in the number of pounds gained per day is expected to increase profits
Middle Average Daily Gain (MIDADG)	Average pounds of gain per day per head middle 56-83 days on feed	(+) increase in the number of pounds gained per day is expected to increase profits
End Average Daily Gain (ENDADG)	Average pounds of gain per day per head for the last 61 - 98 days on feed	(+) increase in the number of pounds gained per day is expected to increase profits
Beginning Feed Intake (BEGIT)	Average pounds of feed consumed per day per head during the first 44-66 days on feed	(-) an increase in the number of pounds of feed consumed is expected to decrease profits
Middle Feed Intake (MIDIT)	Average pounds of feed consumed per day per head middle 56-83 days on feed	(-) an increase in the number of pounds of feed consumed is expected to decrease profits
End Feed Intake (ENDIT)	Average pounds of feed consumed per day per head for the last 61 - 98 days on feed	(-) an increase in the number of pounds of feed consumed is expected to decrease profits

Economic Data

Economic data included an estimated value of the steer at the time of placement, actual cost of all individual feeds fed during each year's feeding period, medical expenses for steers requiring treatment during the feeding period, final price received at slaughter for each individual steer (steers were sold using grid pricing which includes premiums and discounts for yield and quality grades), and calculated profit/loss for each steer.

DFCS is a consignment feedlot operation meaning that the cow/calf producer retains ownership of the cattle placed in the feedlot. The cow/calf producer incurs the costs related to feeding the steers to market weights and is charged a yardage fee to cover the fixed costs of running the operation. The producer is then paid the net proceeds received from the packing plant after slaughter. Retaining ownership means that the cost of purchasing cattle to place in the feedlot was not incurred directly by the feedlot and an estimated placement value had to be used as a purchase price for this study.

The estimated placement value or purchase price (PP) of the steers was calculated and provided by Karl Hoppe at NDSU-CREC from a simple regression equation created in Excel for each placement year. Price data were collected for the week before and week after the weigh-in at Turtle Lake from the United State Department of Agriculture's livestock price reports for four Eastern North Dakota sales barns (Central Livestock Auction, West Fargo; Jamestown Livestock Auction, Jamestown; Kist Livestock Auction, Mandan,; Napoleon Livestock Auction, Napoleon). These prices and the cattle weights corresponding with them were entered into Excel. Then using the *Data Analysis* tool from the *Analysis Tool-Pak Excel Add-Ins* a regression equation was created with the steer feeder cattle price per hundred weight (cwt) as the p_i variable and the steer weight as the z_i variable.

(5) $p_i = \gamma_0 + \gamma_1 z_i$

Individual p_i was than calculated for each steer by entering its initial weight at Turtle Lake as the z_i in the equation to generate the p_i for each steer (K. Hoppe, e-mail correspondence, August 24, 2012). An average PP for the pen was then calculated by adding together all p_i for the pen and dividing by the number of steers in the pen at the time of placement.

Sale prices (SP) were reported to the feedlot by the packing plant. Cattle were sold on a grid pricing system (see Appendix Table A2) subjecting them to a base price which was adjusted with premiums and discounts assigned according to their Yield Grade (see Appendix Table A3) and Quality Grade (see Appendix table A4).

Feed costs (FEED$) per head were calculated by taking the total cost of feed for the feeding year and dividing it by total gains of all steers for the year. The cost per pound of gain was then multiplied by each individual animals gain and an average was taken of the total cost per head for the pen.

Medical costs (MED) were reported as the cost of treating steers that were either ill or injured during the feeding period. The costs of treatments were provided on an individual animal basis, this data were used to calculate an average cost per head across each pen. Totaling the cost of all animals treated in the pen and dividing it by the total number of animals placed in the pen. Vaccinations were not included in medical costs, they were considered an overhead cost in this study, vaccinations are administered to all incoming cattle regardless of pen characteristics thus there is no variation in the cost per pen for vaccinations.

TABLE 4: Description of Economic Parameters

Variable	Description	Expected Outcome
Purchase Price (PP)	Average price per cwt value of calves in the pen	(-) an increase in purchase price is expected to decrease profits
Sale Price (SP)	Average price per cwt received per head in the pen	(+) an increase in selling price is expected to increase profits per head
Feed Cost (FEED$)	Average feed cost calculated as $/head	(-) an increase in the cost of feed is expected to decrease profits
Medical Cost (MED)	Average cost of medical treatments per head in the pen	(-) an increase in the cost of treatments is expected to decrease profits

Weather Data

Weather risk in cattle finishing has been studied by animal scientists with emphasis placed on the effects of cold weather on dietary requirements (Mader et al, 2001), wind protection (Anderson & Bird, 1993, Mader, Dahlquist, & Gaughan, 1997), and bedding (Anderson, Aberle, & Swenson, 2004). Indexes have also been developed to predict animal comfort levels during different types of weather conditions (Oklahoma State University, 2012).

Mader, Johnson, and Gaughan (2010) developed a comprehensive climate index (CCI) that can be used to calculate cattle stress levels during both cold and hot seasons. This index uses wind speed (WS), relative humidity (RH) and solar radiation (RAD) to adjust ambient temperature (TA) to an apparent temperature that can be used to explain cold and heat stress levels in cattle. The use of relative humidity in this index helps to incorporate stress related to precipitation during cold weather. During humid conditions the hair coat and hide of cattle raised in outside conditions becomes damp causing a loss of body heat. The index used by Belasco and Cheng (2011) used coat condition to determine impacts of the wind chill temperature on stress levels (see Appendix Table A5). The cold stress model indicates that precipitation of 0.10 inches during the last hour of a six hour period calculated cold stress would be the same as a dry summer coat on the index chart more precipitation would then move the calculated cold stress to Wet conditions on the index chart (Oklahoma State University, 2012). We were unable to obtain hourly precipitation data from NDAWN to calculate the coat conditions for the cold stress in this model making the CCI the best choice for our study.

To calculate the CCI weather data were collected from NDAWN at hourly intervals beginning at 1:00 a.m. on the date the steers were brought to Turtle Lake, ND for weigh-in, through midnight (24:00) the date that the steers left the NDSU-CREC feedlot for slaughter.

Weather data collected included temperature (TA) reported in degrees Fahrenheit (°F), wind speeds (WS) reported in miles per hour (MPH), relative humidity (RH) reported in a percent (%), and solar radiation (RAD) reported in a Langley (LYS) measurement. TA, WS, and RAD data collected required conversions to different units to calculate the CCI correctly. TA was converted from degrees Fahrenheit (°F) to degrees Celsius (°C), WS was converted from MPH to meters per second (m/s), and RAD was converted from LYS to kilocalories per meter squared ($Kcal/m^2$).

The data collected was converted to units used by the CCI, through the following equations:

Temperature (TA) degrees Fahrenheit (°F) to degrees Celsius (°C):

(6) TA(°C) = 5/9 * (TA(°F)-32)

Wind speed (WS) miles per hour (MPH) to meters per second (m/s):

(7) WS(m/s) = WS(MPH) * 0.44704

Solar Radiation (RAD) Langley (LYS) to kilocalories per meter squared ($Kcal/m^2$):

(8) RAD ($Kcal/m^2$) = RAD(LYS) * 10

The converted data were then used to calculate cattle cold stress levels using the comprehensive climate index (CCI) developed by Mader, Johnson, and Gaughan (2010). The CCI adjusts ambient temperature (TA) for wind speed (WS), relative humidity (RH), and solar radiation (RAD). The CCI or apparent temperature is calculated using the following formula:

$$CCI = TA + Eq.[A] + Eq.[B] + Eq.[C]$$

Equation [A] RH correction factor =

$$e^{(0.00182xRH + 1.8x10^{-5}xTaxRH)}x(0.000054xTA^2 + 0.00192xTA - 0.0246)x(RH - 30)$$

Equation [B] WS correction factor =

$$\frac{-6.56}{e^{\left(\frac{1}{(2.26xWS+0.23)^{(0.45x(2.9+1.14x10^{-6}xWS^{2.5}-log_{0.3}(2.26xWS+0.33)^{-2})}}\right)}}-0.00566xWS^2+3.33$$

Equation [C] RAD correction factor =

$$0.0076xRAD-0.00002xRADxTA+0.00005xTA^2x\sqrt{RAD}+0.1xTA-2$$

The calculated hourly CCI was then evaluated to determine number of hours of exposure to each level of cold stress as defined by the table *Thresholds for Heat and Cold Stress Indicies* (see Appendix A6). A day of severe cold stress was then defined to be any day that included six or more consecutive hours of cold stress at the severe level or worse (extreme and dangerous levels) during a 24 hour period that begins at 12:00 pm (noon) and ends at 12:00 pm the next day.

TABLE 5: Description of Weather Risk Parameters

Variable	Description	Expected Outcome
Percent Beginning Severe (PBEGSEV)	Number of days during the first 44-66 days on feed with a minimum of 6 hours of cold stress at the severe level or worse (severe being an apparent temperature of <-20 to -30°C; <-4 to -22°F) calculated as a percent of number of days on feed (DOF) during the segment	(-) an increase in percent of days with severe cold stress is expected to decrease profits
Percent Middle Severe (PMIDSEV)	Number of days during the middle 56-83 days on feed with a minimum of 6 hours of cold stress at the severe level or worse (severe being an apparent temperature of <-20 to -30°C; <-4 to -22°F) calculated as a percent of number of days on feed (DOF) during the segment	(-) an increase in percent of days with severe cold stress is expected to decrease profits
Percent End Severe (PENDSEV)	Number of days during the last 61-98 days on feed with a minimum of 6 hours of cold stress at the severe level or worse (severe being an apparent temperature of <-20 to -30°C; <-4 to -22°F) calculated as a percent of number of days on feed (DOF) during the segment	(-) an increase in percent of days with severe cold stress is expected to decrease profits

Summary Statistics

Summary statistics of data used in this analysis are presented in Table 5-Table 8. The statistics summarized in Table 5 are an overall summary of all of the data collected. The statistics summarized in Table 6 through Table 8 presents the data by placement weight block (L, M, and H). The summary statistics have been presented for weight block to show the differences in pen numbers, average weights, animal performance and economic variables between each block. These differences are important in understanding the effect of the management decision behind initial placement weights of cattle.

A total of 98 pens of steers were used in this analysis, which included 42 pens of L steers averaging 560.77 pounds at placement (IN), 44 pens of M steers averaging 656.91 pounds IN and 12 pens of H steers averaging 729.23 pounds IN. The finished weight (OUT) of the three blocks shows that each block was sent to slaughter at different finished weights, L finished at an average of 1287.3 pounds, M at 1383.44 pounds, and H at 1449.89 pounds. All blocks have DOF that average approximately 200 days, typically lighter weight placements would be expected to spend more time in the feedlot than heavier weight placements, depending on the frame size the steers and management marketing decisions based on the daily costs of feeding. Purchase price (PP) for the blocks is higher for lighter weight blocks than heavier weight blocks, this is consistent with market prices for cattle. The average number of days of exposure to severe cold stress (SEV) for the H block is almost 20 days more than for the L and M blocks. The H blocks were placed in 2006, 2008, and 2010; these three feeding periods included severe cold stress days totaling 66, 94, and 92 days respectively, compared to 52, 63 and 41 in 2005, 2009, and 2011 respectively (see Appendix Table A7). There were only 12 pens of H block cattle placed over the six years included in this study.

TABLE 6: Overall Summary Statistics, 98 Pens

Variable	Units	Mean	Std Dev	Min	Max
Management					
HDIN	Hd	9.62	1.10	7.00	11.00
HDOUT	Hd	9.52	1.14	6.00	11.00
IN	Lbs	623.13	67.26	508.75	815.00
OUT	Lbs	1350.37	86.32	1140.11	1537.06
DOF	Days	201.33	6.52	191.00	212.00
BEGDOF	Days	57.71	7.06	44.00	66.00
MIDDOF	Days	64.71	11.23	56.00	83.00
FINDOF	Days	78.90	12.42	61.00	98.00
Performance					
ADG	Lbs/day	3.62	0.31	3.21	4.72
BEGADG	Lbs/day	3.76	0.40	2.67	5.32
MIDADG	Lbs/day	3.70	0.38	3.00	4.60
ENDADG	Lbs/day	3.48	0.45	2.54	4.64
IT	Lbs/Hd/Day	30.67	2.64	24.67	38.71
BEGIT	Lbs/Hd/Day	26.97	3.36	16.32	36.29
MIDIT	Lbs/Hd/Day	31.41	3.23	24.27	40.00
ENDIT	Lbs/Hd/Day	32.40	2.86	27.70	40.21
Weather					
SEV	Days	68.71	19.93	41.00	95.00
BEGSEV	Days	13.96	5.79	4.00	23.00
MIDSEV	Days	39.69	20.32	12.00	73.00
ENDSEV	Days	15.06	8.01	1.00	24.00
PSEV	% days	0.34	0.10	0.21	0.48
PBEGSEV	% days	0.24	0.09	0.09	0.39
PMIDSEV	% days	0.59	0.23	0.21	0.88
PENDSEV	% days	0.18	0.10	0.02	0.31
HCW	Lbs	815.68	53.57	690.11	940.63
PP	$/cwt	124.11	31.79	90.01	196.60
SP	$/cwt	151.07	19.59	119.75	189.74
FEED$	$/hd	377.93	137.64	178.64	654.10
MED	$/hd	4.18	4.43	0.00	28.20
PROFIT	$/hd	94.55	128.13	-160.40	347.55

TABLE 7: Summary Statistics by Weight Block – Light (L), 42 Pens

Variable	Units	Mean	Std Dev	Min	Max
Management					
HDIN	Hd	9.57	1.04	8.00	11.00
HDOUT	Hd	9.43	1.19	6.00	11.00
IN	Lbs	557.42	26.77	508.75	595.00
OUT	Lbs	1287.30	63.97	1140.11	1442.79
DOF	Days	202.67	6.03	197.00	212.00
BEGDOF	Days	59.10	6.34	44.00	66.00
MIDDOF	Days	63.60	10.47	56.00	83.00
ENDDOF	Days	79.98	13.30	61.00	98.00
Performance					
ADG	Lbs/day	3.62	0.35	3.21	4.72
BEGADG	Lbs/day	3.71	0.46	2.67	5.32
MIDADG	Lbs/day	3.66	0.40	3.00	4.49
ENDADG	Lbs/day	3.55	0.43	2.80	4.64
IT	Lbs/Hd/Day	29.45	2.5	24.67	35.73
BEGIT	Lbs/Hd/Day	25.37	3.00	16.32	32.31
MIDIT	Lbs/Hd/Day	30.10	3.06	24.27	37.79
ENDIT	Lbs/Hd/Day	31.74	3.15	27.70	39.59
Weather					
SEV	Days	65.81	20.29	41.00	95.00
BEGSEV	Days	14.76	5.42	4.00	23.00
MIDSEV	Days	36.62	19.39	12.00	73.00
ENDSEV	Days	14.43	8.69	1.00	24.00
PSEV	% days	0.33	0.10	0.21	0.48
PBEGSEV	% days	0.25	0.09	0.09	0.39
PMIDSEV	% days	0.55	0.23	0.21	0.88
PENDSEV	% days	0.17	0.10	0.02	0.27
HCW	Lbs	775.45	38.50	690.11	879.29
PP	$/cwt	130.73	32.46	98.66	195.60
SP	$/cwt	152.69	20.43	119.75	189.51
FEED$	$/hd	381.72	146.72	197.59	654.10
MED	$/hd	4.59	5.10	0.00	28.20
PROFIT	$/hd	80.71	129.20	-160.40	302.72

TABLE 8: Summary Statistics by Weight Block - Medium (M), 44 Pens

Variable	Units	Mean	Std Dev	Min	Max
Management					
HDIN	Hd	9.64	1.12	7.00	11.00
HDOUT	Hd	9.57	1.09	7.00	11.00
IN	Lbs	656.90	27.82	617.22	697.50
OUT	Lbs	1383.44	69.09	1266.40	1537.06
DOF	Days	199.66	6.62	191.00	212.00
BEGDOF	Days	57.75	7.08	44.00	66.00
MIDDOF	Days	64.89	11.41	56.00	83.00
ENDDOF	Days	77.02	11.58	61.00	97.00
Performance					
ADG	Lbs/day	3.64	0.30	3.23	4.28
BEGADG	Lbs/day	3.77	0.36	2.96	4.42
MIDADG	Lbs/day	3.76	0.39	3.12	4.60
ENDADG	Lbs/day	3.46	0.49	2.54	4.37
IT	Lbs/Hd/Day	31.24	2.47	27.73	38.71
BEGIT	Lbs/Hd/Day	27.73	3.17	22.39	36.29
MIDIT	Lbs/Hd/Day	31.97	3.00	26.67	40.00
ENDIT	Lbs/Hd/Day	32.82	2.77	28.36	40.21
Weather					
SEV	Days	67.16	19.33	41.00	95.00
BEGSEV	Days	13.61	5.44	4.00	23.00
MIDSEV	Days	38.86	20.67	12.00	73.00
ENDSEV	Days	14.68	8.22	1.00	24.00
PSEV	% days	0.34	0.10	0.21	0.48
PBEGSEV	% days	0.23	0.09	0.09	0.39
PMIDSEV	% days	0.57	0.23	0.21	0.88
PENDSEV	% days	0.19	0.11	0.02	0.31
Economic					
HCW	Lbs	837.69	42.87	760.30	940.63
PP	$/cwt	123.07	33.28	90.01	196.60
SP	$/cwt	148.41	18.01	123.78	188.44
FEED$	$/hd	366.22	139.42	178.64	593.85
MED	$/hd	4.20	3.96	0.00	12.46
PROFIT	$/hd	103.90	134.81	-111.05	347.55

TABLE 9: Summary Statistics by Weight Block - Heavy (H), 12 Pens

Variable	Units	Mean	Std Dev	Min	Max
Management					
HDIN	Hd	9.75	1.29	8.00	11.00
HDOUT	Hd	9.67	1.23	8.00	11.00
IN	Lbs	729.23	29.38	700.00	815.00
OUT	Lbs	1449.89	37.76	1364.27	1498.00
DOF	Days	202.75	6.94	197.00	212.00
BEGDOF	Days	52.75	7.72	44.00	59.00
MIDDOF	Days	68.00	13.29	56.00	83.00
ENDDOF	Days	82.00	12.14	70.00	97.00
Performance					
ADG	Lbs/day	3.56	0.21	3.26	3.90
BEGADG	Lbs/day	3.90	0.35	3.30	4.44
MIDADG	Lbs/day	3.63	0.26	3.24	3.94
ENDADG	Lbs/day	3.31	0.35	2.76	3.85
IT	Lbs/Hd/Day	32.86	1.48	30.87	36.73
BEGIT	Lbs/Hd/Day	29.76	2.53	25.17	35.99
MIDIT	Lbs/Hd/Day	33.92	2.73	30.42	39.00
ENDIT	Lbs/Hd/Day	33.18	1.54	30.48	36.54
Weather					
SEV	Days	84.58	13.78	66.00	95.00
BEGSEV	Days	12.42	8.07	4.00	23.00
MIDSEV	Days	53.50	17.96	34.00	73.00
ENDSEV	Days	18.67	2.06	17.00	22.00
PSEV	% days	0.42	0.08	0.31	0.48
PBEGSEV	% days	0.22	0.13	0.09	0.39
PMIDSEV	% days	0.77	0.12	0.61	0.88
PENDSEV	% days	0.23	0.04	0.18	0.27
Economic					
HCW	Lbs	875.73	23.48	822.45	920.38
PP	$/cwt	104.78	8.59	92.55	112.88
SP	$/cwt	155.16	22.41	120.54	189.74
FEED$	$/hd	407.60	96.29	333.22	574.54
MED	$/hd	2.68	3.36	0.00	10.56
PROFIT	$/hd	108.67	101.04	-96.25	235.88

Empirical Model

To determine how management decisions, animal performance, prices, and weather risk factors affect the profits per head (PROFIT) of North Dakota feedlots the following regression model was defined:

(9) PROFIT = f(YEAR, H, M, L, BEGADG, MIDADG, ENDADG, BEGIT,MIDIT, ENDIT, PBEGSEV, PMIDSEV, PENDSEV, PP, SP, FEED$, MED)

Definitions of these variables along with expected outcomes are provided in Tables 2, 3, and 4 in the data section of this study.

RESULTS

The data were analyzed using an Ordinary Least Squares (OLS) regression model. All management, performance, economic and weather risk variables discussed in the data section of this paper were included in the model along with a year effect for time trend and variables representing the interactions between each performance variable and weather risk during each segment. The two models were created to allow for comparisons between them. The model was tested for the presence of heteroskedasticity or unequal error variances using the White Test (Wooldridge, 2003), no heteroskedasticity was found thus no corrections were made for heteroskedasticity in the model.

Model

Results for the model are presented in Table (10). The positive coefficient on the management decision variables M and H indicate that in comparison to the light weight group heavier cattle are more profitable to feed in North Dakota ($P < 0.01$). This is inconsistent with the findings of Lawrence, Wang, and Loy (1999) who found that light weight cattle <600 pounds were more profitable to feed in the Midwest than heavier weight cattle. Since the time that Lawrence, Wang, and Loy's (1999) study was completed corn prices have risen substantially. This increase in input costs reduces the profitability of light weight cattle (< 600 lbs) which take longer to reach market weights than heavier weight cattle (> 600 lbs).

Cold stress is known to affect the performance of feedlot steers, although there is not a high correlation between the performance variables and weather risk variables in this study (see Appendix Table A8) it is believed that the effects of the performance variables is being represented in the parameter estimates of the weather risk variables. The positive effect of

ENDADG ($P < 0.10$) was expected as an increase in average daily gain increases the market weight of the cattle thus increasing overall revenues received.

Weather risk variables for percent of days with severe cold stress during two segments of the feeding period show statistically significant effects on feedlot profits in North Dakota. A 1% increase in the number of days with severe cold stress during the middle (PMIDSEV) segment shows a positive effect on profit, this positive effect is unexpected and suggests that severe cold stress endured during the middle segment of the feeding period does not reduce efficiency of the steers to the point that profits are negatively affected. The end (PENDSEV) segment shows that severe cold stress during the end of the feeding period has a negative and larger effect on profits compared to the rest of the feeding period. This is consistent with findings by Belasco and Cheng (2011) as exposure to cold stress reaches a threshold of 90 days it begins to reduce profits. During the early and middle portions of the feeding period light weight calves are experiencing compensatory gains due to an increase in high quality feed in their diet. At the end of the feeding period the growth of fat versus lean muscle is increasing, they become less efficient at converting feed to weight gain as their body increases the proportion of fat growth to muscle growth. More feed is needed to produce fat than lean, thus average daily gains and feed efficiency begin to taper off (Field, 2007). Severe cold stress during the end segment of the feeding period decreases the efficiency of the cattle even more as more energy is required for maintenance.

Sale price (SP) and medical costs (MED), medical costs were found to be the only two economic variables statistically significant ($P < 0.01$). As expected SP has a positive effect on profits of North Dakota feedlots, and MED has a negative effect. The lack of significance for PP and FEED$ may be due to the fact that PP is calculated as an estimated value at time of placement and FEED$ is calculate from an overall cost per pound of gain, not from actual cost of feed fed to the pen, whereas SP and MED were calculated from actual price and expense data. It should be noted that the cattle in this study were sold on a grid pricing scale, which sets a base price on the weight of the steer than assesses premiums and discounts according to Yield and Quality Grades (see Appendix Tables A2, A3, & A4) on a price per hundred weight. Significance of the selling price and its effect on profits may change with a different selling strategy.

TABLE 10: Results OLS Analysis Percent Severe, Profit

Variable	**Parameter Estimate**	**Standard Error**	**t-value**	**P-value.**	**Sign**[1,2,3]
Year	-0.323	0.9868	-0.33	0.7442	
Management					
H	66.941	21.5609	3.10	0.0026	***
M	56.136	11.6960	4.80	<.0001	***
Performance					
BEGADG	28.370	18.0206	1.57	0.1193	
BEGIT	-3.601	3.0621	-1.18	0.2431	
MIDADG	25.171	24.1667	1.04	0.3007	
MIDIT	2.860	3.3141	0.86	0.3907	
ENDADG	41.591	22.7438	1.83	0.0711	*
ENDIT	-4.804	4.4202	-1.09	0.2803	
Weather Risk					
PBEGSEV	166.780	143.0175	1.17	0.2470	
PMIDSEV	254.822	142.5859	1.79	0.0777	*
PENDSEV	-928.934	111.4950	-8.33	<.0001	***
Economics					
PP	0.903	1.1020	0.82	0.4150	
SP	3.716	0.8743	4.25	<.0001	***
FEED$	-0.408	0.3277	-1.25	0.2163	
MED	-4.310	1.0297	-4.19	<.0001	***
Intercept	-627.452	353.0470	-1.78	0.0793	*
R^2	0.9289				
Adj R^2	0.9148				
Durbin-Watson D Pr < DW Pr > DW # of Obs 1st Order AutoCorr	1.988 0.2738 0.7262 98 0.005				

[1] ***P-value < 0.01
[2] **P-value < 0.05
[3] *P-value < 0.10

Limitations of the Study

Data for this study were collected from feeding trials done at North Dakota State University's Carrington Research and Extension Center. The purpose of the studies completed at NDSU-CREC is to simulate a true feedlot operation in North Dakota with an emphasis on the effects of different feeding systems. Due to this, certain management and economic decisions of the feedlot at NDSU-CREC are made differently than those made by a profit maximizing producer, by taking the needs of the experiment into consideration first and the maximization of profits second. In the feed trials used for this analysis, cattle are grouped into four smaller pens by size, in a profit maximizing feedlot larger pen sizes would be typical to reduce labor costs and to reduce transportation costs to the packing plant. A pen of 36 to 40 head of steers finished to an average weight of approximately 1,100 to 1,250 pounds is enough weight to fully load a semi, thus a pen of this size can be shipped at finishing even if other pens are not ready to go at the same time without increasing transportation costs.

At NDSU-CREC the cattle in the feedlot are used in feeding trial where the main goal is to determine how production variables change with different levels of a chosen feed component. Procurement of feeds at NDSU-CREC is done after the decision of what will be fed is made and is not based on the least cost ration. In a profit maximizing feedlot feeding decisions would be made by choosing feeds according to availability and price of key feed ingredients that create a least cost ration.

Another limitation is the selling decision made at NDSU-CREC, all cattle were taken to slaughter on the same dates each year[5], generally cattle placed at heavier weights will finish faster than lighter placement weights, because this is not seen in this data set we do not have a

[5] Calves placed in 2005 were sent to slaughter on two different dates, this was the only time in this study that this happened.

variation in the number of days on feed between pens that would be seen in a typical feedlot. This also causes there to be higher average finishing weights in the heavier placement blocks which may have overstated the efficiency and value of placing heavy weight cattle versus lighter weights.

The collection of periodic weights taken may also be a limitation in our data. Lack of consistency in the point during the feeding period that weights were taken across years caused days of severe cold stress that would have been calculated in the ending segment of the majority of the years to be calculated as part of the middle segment in two of the years (see Appendix Table A1).

CONCLUSIONS

The cattle industry in North Dakota faces many challenges by expanding into the feedlot sector. One of those challenges is the exposure of feeder cattle to severe cold stress during North Dakota winters which has the potential to reduce profits through lost performance and increased feed costs. Although cattle have a lower critical temperature than most other domesticated livestock species (National Research Council, 1981), long periods of temperatures below freezing combined with high wind speeds and heavy snow falls in North Dakota create cold stress conditions that have the potential to affect the profitability of the feedlot. Quantifying the effects of weather risk on the profitability of the feedlot will help producers to make decisions about the risks of feeding cattle in North Dakota's harsh winter weather conditions to meet the demand increases for fed cattle with the opening of a packing plant in Aberdeen S.D.

As we had anticipated the results from this study indicate that exposure to severe cold stress during the feeding period reduces the profitability of cattle in the feedlot. These indications lead us to believe that expanding the feedlot sector of the North Dakota cattle industry will require investment in infrastructures that could help to reduce the effects of severe cold stress on feedlot cattle such as additional windbreaks during winter feeding periods or indoor feeding facilities such as hoop barn structures similar to those used in the dairy industry in Minnesota and Wisconsin.

The results for our management decision variables indicate that the placement of steers weighing greater than 600 pounds during the fall in North Dakota is more profitable than placing lighter weight steers. This is inconsistent with Lawrence, Wang, and Loy's (1999) findings that light weight cattle were more profitable to feed in the Midwest than heavier weight cattle. Their findings were based on data from feedlots in states that were located in warmer climates, south of where our data was collected and included data from other placement seasons when lighter weight cattle are exposed to less cold stress and may perform more efficiently. Also, their study was done in the late 1990's when corn prices were substantially lower, increased corn prices increases the cost of feeding lighter weights steers that take longer to finish.

While this research provides some insight into the understanding of how severe cold stress affects the profitability of the feedlot in North Dakota, further research is needed to make determinations about the diversification of the cattle industry into the feedlot sector. One way to further this research would be to acquire data from feedlots operating in North Dakota in areas where the majority of cattle are fed to finish. Although Carrington, ND is centrally located between many of North Dakota's feedlots the majority of cattle fed to finish in the state are fed in more southern regions of the state (USDA-NASS, 2008). Data from operating feedlots would also allow us to capture effects of management decisions, price risks, selling decisions, and facilities on profitability giving insight into the economics of feeding cattle to finish in North Dakota.

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APPENDIX

TABLE A1: Dates of Weights Taken Throughout Feeding Period.

	Dates						
Year	Weight 1 (W1)	Weight 2 (W2)	Weight 3 (W3)	Weight 4 (W4)	Weight 5 (W5)	Weight 6 (W6)	Weight 7 (W7)
2005-06	11/14/05	12/12/05	01/09/06	02/06/06	03/15/06	04/21/06	05/15/06[1]
2006-07	11/21/06	12/19/06	01/16/07	02/13/07	03/13/07	04/10/07	05/21/07
2008-09[2]	11/04/08	12/04/08	01/29/09	02/25/09	04/06/09	05/06/09	N/A[3]
2009-10	11/19/09	12/18/09	02/02/10	03/04/10	04/01/10	05/04/10	N/A[3]
2010-11	11/16/10	12/14/10	01/11/11	02/11/11	03/11/11	05/03/11	N/A[3]
2011-12	11/22/11	12/20/11	01/17/12	02/14/12	03/13/12	04/10/12	05/01/12

[1] Only 8 of the 16 pens fed in 2005-06 had a weight 7. The other 8 were sent to slaughter the day weight 6 was taken.

[2]Pen level feeding data were not collected for the fall 2007 placements; therefore data from this placement year were not included in this study.

[3]Weight 7 containing N/A in place of a date designates the years when cattle were sent to slaughter after only six weights were taken. This may be due to a shorter time on feed or a longer number of days experienced between weights taken due to management discretion.

TABLE A2: Example Value-Based Carcass Price Grid. (Naze, Dhuyvetter, and Poland, 1999).

Value based price grid Base Price = $103.00 Weight range 535-950	
USDA Quality Grade	**$/cwt**
Prime	6.00
Choice	2.00
Select	-3.00
Standard	-13.00
USDA Yield Grade	**$/cwt**
YG1	3.00
YG2	1.00
YG3	-1.00
YG4	-20.00
YG5	-20.00

TABLE A3: USDA Yield Grading System (Naze, Dhuyvetter, and Poland, 1999).

Yield Grade[1]	**Percentage of closely trimmed retail product**
1	75.5%
2	71.5%
3	67.5%
4	64.9%
5	60.8%

[1] mostly boneless cuts from the round, loin, rib, and chuck

TABLE A4: USDA Beef Carcass Quality Grades (Naze, Dhuyvetter, and Poland, 1999)[1].

Relationship Between Marbling, Maturity, and Carcass Quality Grade[2]						
Degrees of Marbling	**Maturity**[3]					**Degrees of Marbling**
	A[4]	**B**	**C**	**D**	**E**	
Slightly Abundant	**Prime**					**Slightly Abundant**
Moderate			**Commercial**			**Moderate**
Modest	**Choice**					**Modest**
Small						**Small**
Slight	**Select**			**Utility**		**Slight**
Traces					**Cutter**	**Traces**
Practically Devoid	**Standard**					**Practically Devoid**

[1] Adapted from "Figure 2: USDA Beef Grading Chart"
[2] Assumes that firmness of lean is comparably developed with the degree of marbling and that the carcass is not a "dark cutter."
[3] Maturity increases from left to right (A through E).
[4] The A maturity portion of the table is the only portion applicable to bullock carcasses.

TABLE A5: Thresholds for Heat and Cold Stress Indicies (Oklahoma State University, 2012 and Belasco and Cheng, 2011).

Index	**Description**	**Time**	**Mild**	**Moderate**	**Severe**
THI	Heat Stress	Year-round	72-79	80-89	>90
WCI **Cattle Coat**	Cold Stress				
Dry heavy		Jan 1-Mar 31	19-10	9-0	<0
Dry Spring		Apr 1-Apr 30	45-32	31-18	<18
Dry Summer		May 1-Oct 15	59-46	45-32	<32
Dry Fall		Oct 16-Nov 30	45-32	31-18	<18
Dry Winter		Dec 1-Dec 30	32-20	19-7	<7
Wet		Year-round	59-46	45-32	<32

TABLE A6: Comprehensive Climate Index Thermal Stress Thresholds (Mader, Johnson and Gaughan, 2010).

		Cold Conditions	
		Animal susceptibility	
Environment	**Hot Conditions**	**High[1]**	**Low[2]**
No Stress	<25	>5	>0
Mild	25 to 30	0 to 5	0 to -10
Moderate	>30 to 35	<0 to -5	<-10 to -20
Severe	>35 to 40	<-5 to -10	<-20 to -30
Extreme	>40 to 45	<-10 to -15	<-30 to -40
Extreme danger	>45	<-15	<-40

[1]Generally, young or nonacclimated animals or both cared for under sheltered or modified environmental conditions.
[2]Generally, unsheltered animals that have had adequate time to acclimate to outdoor environments through acquisition of additional external or tissue insulation or both and are receiving nutrient supplies compatible with the level of environmental exposure.

TABLE A7: Summary Statistics by Year

	2005-06 (1)	2005-06 (2)	2006-07	2008-09	2009-10	2010-11	2011-12
PENS	8	8	16	18	16	16	16
H	0	0	4	5	0	3	0
M	8	8	8	8	8	5	7
L	0	0	4	5	8	8	9
HDIN	10.38	10.50	8.63	10.89	9.88	9.75	8.00
HDOUT	10.38	10.50	8.56	10.67	9.81	9.69	7.81
IN	660.36	554.61	644.71	648.40	625.00	615.96	594.04
OUT	1316.06	1278.98	1364.00	1326.11	1337.13	1355.33	1425.16
DOF	191.00	212.00	212.00	197.00	199.00	200.00	199.00
BEGDOF	58.00	58.00	59.00	44.00	62.00	59.00	66.00
MIDDOF	56.00	56.00	56.00	83.00	76.00	59.00	56.00
ENDDOF	77.00	98.00	97.00	70.00	61.00	82.00	77.00
ADG	3.43	3.42	3.39	3.46	3.58	3.70	4.20
BEGADG	3.87	3.84	3.38	3.55	3.72	3.92	4.18
MIDADG	3.87	3.63	3.68	3.36	3.36	3.79	4.30
ENDADG	2.78	3.03	3.17	3.49	3.70	3.48	4.13
IT	29.04	27.43	30.33	30.63	29.71	30.55	34.57
BEDIT	23.85	20.90	26.61	28.02	27.69	26.68	30.31
MIDIT	30.01	27.61	29.22	31.10	30.30	33.70	35.36
ENDIT	32.25	31.20	31.98	31.35	30.81	30.94	37.74
SEV	52.00	52.00	66.00	95.00	63.00	92.00	41.00
BEGSEV	16.00	16.00	15.00	4.00	15.00	23.00	12.00
MIDSEV	12.00	12.00	34.00	73.00	47.00	47.00	21.00
ENDSEV	24.00	24.00	17.00	18.00	1.00	22.00	8.00
PSEV	0.27	0.25	0.31	0.48	0.32	0.46	0.21
PBEGSEV	0.28	0.28	0.25	0.09	0.24	0.39	0.18
PMIDSEV	0.21	0.21	0.61	0.88	0.62	0.80	0.38
PENDSEV	0.31	0.24	0.18	0.26	0.02	0.27	0.10
HCW	799.98	775.24	829.00	803.32	812.39	802.32	860.96
PP /CWT	125.18	133.19	117.16	98.35	97.05	116.64	189.51
SP /CWT	127.21	124.35	154.73	135.67	155.27	186.24	150.67
FEED$/HD	184.14	203.42	334.43	362.93	267.90	541.56	568.84
FEED$/LB GAIN	0.28	0.28	0.47	0.54	0.38	0.74	0.70
MED/HD	3.00	0.67	2.82	3.93	5.53	5.06	5.95
PROFIT/HD	-90.36	-76.55	115.66	5.18	293.65	163.57	83.87

TABLE A8: Correlation of Variables

	H	M	L	BEGADG	BEGIT	MIDADG	MIDIT	ENDADG
H	1.000	-0.3372	-0.3235	0.1263	0.3116	-0.0654	0.2922	-0.1387
M	-0.3372	1.000	-0.7817	0.0276	0.2051	0.1380	0.1567	-0.0382
L	-0.3235	-0.7817	1.000	-0.1115	-0.4126	-0.0954	-0.3510	0.1302
BEGADG	0.1263	0.0276	-0.1115	1.000	0.4134	0.4691	0.6185	0.2469
BEGIT	0.3116	0.2051	0.4126	0.4134	1.000	0.1777	0.7354	0.5093
MIDADG	-0.0654	0.1380	-0.0954	0.4691	0.1778	1.000	0.5307	0.2752
MIDIT	0.2922	0.1567	-0.3510	0.6185	0.7354	0.5307	1.000	0.4832
ENDADG	-0.1387	-0.0382	0.1302	0.2469	0.5093	0.2752	0.4832	1.000
ENDIT	0.1018	0.1331	-0.2012	0.4961	0.5844	0.7042	0.6599	0.5328
PBEGSEV	-0.0647	-0.0582	0.1013	0.1411	-0.3073	0.1755	0.0216	-0.2529
PMIDSEV	0.2919	-0.0627	-0.1301	-0.3001	0.2756	-0.4692	0.0945	0.1256
PENDSEV	0.1844	-0.0053	-0.1274	-0.0780	-0.3555	-0.0074	-0.0783	-0.5370
PP	-0.2283	-0.0298	0.1812	0.4382	0.1808	0.7767	0.4098	0.4191
SP	0.0785	-0.1233	0.0720	0.0719	0.1807	0.1237	0.3213	0.2499
FEED$	0.0809	-0.0772	0.0240	0.3763	0.5003	0.5448	0.7050	0.6169
MED	-0.1276	0.0044	0.0801	-0.0135	0.1747	0.0690	0.1548	0.2547
PROFIT	0.0414	0.0663	-0.0940	0.0331	0.3342	-0.0898	0.1968	0.3877
YEAR	-0.0737	-0.08844	0.1336	0.4152	0.5637	0.3977	0.6804	0.7792

TABLE A8: Correlation of Variables (Continued)

	ENDIT	PBEGSEV	PMIDSEV	PENDSEV	PP	SP	FEED$	MED
H	0.1018	-0.0647	0.2919	0.1844	-0.2283	0.0785	0.0809	-0.1276
M	0.1331	-0.0582	-0.0627	-0.0525	-0.0298	-0.1233	-0.0772	0.0044
L	-0.2012	0.1013	-0.1303	-0.1274	0.1812	0.0720	0.0240	0.0801
BEGADG	0.4961	0.1411	-0.3001	-0.0780	0.4382	0.0719	0.3763	-0.0135
BEGIT	0.5844	-0.3073	0.2756	-0.3555	-0.1808	0.1807	0.5003	0.1747
MIDADG	0.7042	0.1755	-0.4692	-0.0074	0.7767	0.1237	0.5448	0.0690
MIDIT	0.6599	0.0216	0.0945	-0.0783	0.4098	0.3213	0.7050	0.1548
ENDADG	0.5328	-0.2529	0.1256	-0.5370	0.4191	0.2499	0.6169	0.2547
ENDIT	1.000	-0.2394	-0.3956	-0.2436	0.7552	-0.0926	0.5007	0.1013
PBEGSEV	-0.2394	1.000	-0.1405	0.1452	-0.0320	0.6377	0.1096	-0.0120
PMIDSEV	-0.3956	-0.1405	1.000	0.1323	-0.6000	0.4369	0.2751	0.0997
PENDSEV	-0.2436	0.1452	0.1323	1.000	-0.1621	-0.1161	-0.0196	-0.1850
PP	0.7552	-0.0320	-0.6000	-0.1621	1.000	-0.0303	0.5462	0.0004
SP	-0.0926	0.6377	0.4369	-0.1161	-0.0303	1.000	0.6163	0.1793
FEED$	0.5007	0.1096	0.2751	-0.0196	0.5462	0.6163	1.000	0.1412
MED	0.1013	-0.0120	0.0997	-0.1850	0.0004	0.1793	0.1412	1.000
PROFIT	-0.0695	0.2809	0.3353	-0.6762	-0.1742	0.6543	0.2422	0.0571
YEAR	0.4506	0.0577	0.2186	-0.4655	0.4655	0.5931	0.8467	0.3151

TABLE A8: Correlation of Variables (Continued)

	PROFIT	YEAR
H	0.0414	-0.0737
M	0.0663	-0.0844
L	-0.0940	0.1336
BEGADG	0.0331	0.4152
BEGIT	0.3342	0.5637
MIDADG	-0.0898	0.3977
MIDIT	0.1968	0.6804
ENDADG	0.3877	0.7792
ENDIT	-0.0695	0.4506
PBEGSEV	0.2809	0.0577
PMIDSEV	0.3353	0.2186
PENDSEV	-0.6762	-0.4188
PP	-0.1742	0.4655
SP	0.6543	0.5931
FEED$	0.2422	0.8467
MED	0.0571	0.3151
PROFIT	1.000	0.4814
YEAR	0.4814	1.000