# Probabilistic Models of Yield, Price, and Revenue Risks for Fed Cattle Production

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Agricultural production involves an array of risks that influence the variability of profits derived from crop and livestock enterprises. In the case of crop production, these risks are usually segmented into those that pertain to crop yields and crop prices. Other sources of risk include input prices, liability issues, and unanticipated changes in the value of fixed assets.

An extensive literature has examined models of yield and price risk for crops. Much of this literature has been motivated by the existence of federally-subsidized crop insurance programs. Crop insurance programs, which pay indemnities to participating producers when yields are low, have been an important part of U.S. agricultural policy since the 1930s. The accurate pricing of a crop insurance contract requires a thorough comprehension of the risks underlying the indemnifiable event—crop yield shortfalls. The measurement of such risks has stimulated a rich body of empirical research. Issues of particular interest have included the appropriate approach to model negative skewness and other characteristics of crop yields; the tradeoffs between parametric and nonparametric distribution measures; the importance of inverse correlation between prices and yields; and the systemic nature of crop risks. This literature is summarized in a recent survey by Goodwin and Ker (2002).

In light of the fact that, until recently, agricultural insurance in the United States has been confined to the coverage of crop yield risks, nearly all of the existing empirical research on modeling “yield” risk has applied to crops. However, the 2000 Agricultural Risk Protection Act mandated development of new insurance products, including coverage for livestock. This impetus has heightened the importance of empirical research that addresses models of livestock yield risk. To date, the risk management instruments that have resulted from this legislation have focused on price risk and have largely ignored risks associated with cattle yields.

There are several measures of cattle yield that are analogous to the typical crop yield per acre that is usually studied in empirical research. One such measure is dry matter feed conversion, which is the amount of feed needed per pound of weight gain. Other information, such as mortality losses and the costs associated with veterinary medical services, measure the overall health of the feeder cattle and essentially provide inverse measures of yield. Empirical analysis of these yield factors as well as feed costs and fed cattle prices will allow for a better understanding of how each of these factors contribute to the overall distribution of profits from cattle feeding.

The objective of this paper is to provide a detailed assessment of the yield risks associated with fed cattle production. The analysis is motivated by a larger project that considers models of the *ex-ante* risks associated with cattle feeding. *Ex-ante* risks refer to measures that allow a conditional prediction of the risks associated with yield outcomes at some time in the future. In this context, an important distinction is made between observable, conditioning factors that are relevant to risk at the time the values of decision variables are assigned and other factors that represent unforecastable components of risk. A straightforward example of conditioning factors is obvious in the case of crop yields—where yield models typically condition out the effects of long-run yield trends but not the effects of weather shocks, which cannot be forecast at the time that planting decisions are made. In the case of fed cattle, conditioning factors include those variables that can be chosen at the time that cattle placement decisions are made. The goal of this research is to construct a model of overall fed cattle profit risks, which allows one to provide conditional forecasts of expected profits and other random variables, and to assign a measure of variability to these random outcomes. Within this framework, a number of conditioning factors are considered as well as several random factors which influence profitability.

In the study, models are estimated for the yield variables that provide probabilistic measures of the distributional properties of yield risk. The models allow for certain variables that can be controlled by cattle feeders such as the date of placement on feed, cattle gender, average placement weight, and feedlot location. By accounting for these deterministic factors, estimates of the conditional mean and variance of each variable are computed to describe the risk of cattle yields. This information, as well as estimates of feed costs and fed cattle prices will provide the basis for estimating *ex-ante* profits from cattle feeding. Estimates of expected profits and the factors that affect them will be useful for deriving estimates of the premiums for various livestock revenue insurance contracts which incorporate risks from input and output prices as well as yields.

## Literature Review

Cattle yield or feeding performance has been considered in several empirical studies that focused on cattle feeding profitability risk. Cattle feeding profits are affected by fed and feeder cattle prices, feed grain prices, and yield. As a result, many studies have focused on estimating the individual effects of these factors on profits. Schroeder et al. (1993) evaluated data on over 6,600 pens of steers from two Kansas feedlots and found that 70 to 80 percent of profit variability is explained by fed and feeder cattle prices combined and that corn prices explained 6 to 16 percent of profit variability. The impact of cattle performance, measured as feed efficiency and average daily gain, accounted for less than 10 percent, combined.

Langemeier, Schroeder, and Mintert (1992) found similar results using Kansas feedlot data on 3,300 pens of steers and heifers. Their results indicated that fed and feeder cattle prices accounted for 50 and 25 percent of variability in cattle feeding profits, respectively, while corn prices explained up to 22 percent of the variability. Feed conversion and average daily gain were not as important in explaining profit variability. These variables explained from less than one percent to 3.5 percent of the variability in profits, depending on the placement weight of the cattle. However, differences in feed conversion were found to explain up to 22 percent of the difference between steer and heifer profits over time.

Following these studies, Lawrence, Wang, and Loy (1999) used data from over 200 feedlots in five Midwestern states to determine if differences in climatic conditions represented by data from a wider geographic area would result in cattle performance having a larger impact on profit variability. Animal performance explained more of the variability in profits than the studies using Kansas feedlot data, but fed and feeder cattle prices still accounted for 70 percent of variability in all but one of the groups considered.

Mark, Schroeder, and Jones (2000) updated previous research by using a larger dataset consisting of over 14,000 pens from two Kansas feedlots. The study identified the relative importance of the variables used in the previous studies and also looked at the differences in these factors across pens of cattle with varying sex, placement month, and placement weight. The results of this study were similar to previous work in that both feeder and fed cattle prices are the largest contributors to profit variability. Other findings of the study included differences in the relative explanatory power of the prices and performance characteristics, depending on placement month.

The existing literature on crop yields provides a useful guide to modeling cattle yields in the context of profit variability. The majority of crop yield studies have estimated the conditional mean yield density in an effort to evaluate the risks involved in crop farming and to accurately price crop insurance contracts. The first models employed to characterize mean yield distributions were parametric. Just and Weninger (1999) argued that characterizing crop yields with a normal distribution is not an unreasonable assumption, given their inability to reject normality. However, as discussed by Ker and Coble (2003), yield data tend to be insufficient to statistically invalidate almost all reasonable parametric models.[1] Atwood, Shaik, and Watts (2003) reiterated the importance of not overlooking the normal distribution and argued in favor of proceeding with caution when dealing with heteroskedastic errors.

Other authors have explored the use of the Beta distribution as an alternative to the normal distribution (Nelson and Preckel 1989; Nelson 1990; Coble et al. 1996). The Beta distribution allows for skewness and kurtosis, which is often found in crop yield data. Ker and Coble (2003) used Illinois corn data to show that, while the Beta is superior to the normal in small sample sizes, the opposite is true in larger sample sizes (i.e., greater than 25 observations). Ramirez, Misra, and Field (2003) found that corn and soybean yields are non-normally distributed and negatively skewed. Sherrick et al. (2004) used goodness-of-fit measures to test the economic differences between assuming different distributions. Their results indicate that normal and log-normal distributions fail to describe the sample data as well as the more flexible distributions such as the Beta and

Weibull. Gallagher (1987) used a gamma distribution to characterize the highly skewed nature of crop yields, using a capacity function to illustrate positive skewness.

In addition to parametric characterizations, nonparametric, semi-parametric, and Bayesian estimation techniques have been employed to describe yield variation. These techniques are summarized in Goodwin and Ker (2002) as well as Ker and Goodwin (2000). Parametric methods impose a functional form on the yields that may cause biases if the restrictions do not fit the true mean density. However, with sufficient datasets, semi-parametric and nonparametric methods may be more efficient estimators as they allow the data to determine the most appropriate distribution with few or no restrictions imposed.

**Modeling Cattle Yield**

While several studies have included feed conversion or average daily gain within the profit variability model, health measures like mortality losses and veterinary costs have not been explicitly considered. Cattle yields can be described by dry matter feed conversion (DMFC), which is a ratio indicating the amount of feed required for one pound of weight gain. In this study, the overall health of a given pen of cattle is measured as veterinary costs per head of cattle and the mortality rate of each pen. Each of these variables describes different aspects of overall cattle yield and therefore the risk for cattle feeding associated with yield.

To estimate the density associated with various measures of cattle yields, models for each measure must be specified to account for the deterministic factors (decision variables) involved in cattle feeding. The underlying motivation of these models is to derive probabilistic measures of the distributional properties of yield factors. The first step of the analysis involves the identification of relevant conditioning variables that may be associated with risks of cattle yield but are of a deterministic nature. It is important that these conditioning variables be observable at the time an insurance contract or other risk management instrument is offered (i.e., prior to placement). Conditioning variables such as seasonal effects, pen characteristics, and feedlot-specific fixed effects are included in our empirical models for DMFC, mortality rate, and veterinary costs. Seasonal effects, measured as the date the cattle were placed on feed, account for some of the risks associated with seasonal weather and other environmental factors. Cattle characteristics, such as gender and average placement weight, also represent important conditioning factors that may be relevant to differences in yield for various pens of cattle. Feedlot-specific characteristics may affect risk through differences in geographic location, feedlot management practices, or the predominance of certain breeds of cattle being fed at different locations. Using measures of these conditioning variables, the general forms of each model for yield factors are specified as

(1) *DMFC* = f(*gender, location, in-weight, season*)

(2) *MORT* = f(*gender, location, in-weight, season*)

(3) *VCPH* = f(*gender, location, in-weight, season*)

where *DMFC* is dry matter feed conversion, *MORT* is mortality rate, and *VCPH* is veterinary cost per head. The conditioning variables in each model are: *gender,* a binary variable for steers, heifers, or mixed sex; *location*, a binary variable for feedlot location; i*n-weight*, the average placement weight; and *season*, a binary variable determined by the placement month.

We hypothesize that these conditioning factors may influence mean yields as well as the conditional variability associated with each yield measure.  Thus, each regression for *DMFC*, *MORT*, and *VCPH* was estimated using Harvey's multiplicative heteroskedasticity model (Harvey, 1976).  Harvey's model offers consistent estimates of the parameters with error terms that take into account the correlation with conditioning variables.  While the disturbances may not be independent of conditioning variables, they are believed to be independently and identically distributed.  The model is specified as

$$y_i = \mathbf{x}_i{}'\beta + \varepsilon_i \tag{4}$$

where $\mathbf{x}_i$ is the vector of pen-level conditioning variables and $\varepsilon_i \sim N(0, \sigma_i^2)$.  Specifically, $\mathbf{x}_i$ contains all the individual characteristics used to explain the risk associated with each dependent variable (*gender, location, in-weight, season*).  The conditional variance is unique for each observation and is estimated as

$$\sigma_i^2 = \sigma^2 \exp\left(\mathbf{x}_i{}'\alpha\right) \tag{5}$$

where $\alpha$ contains estimates for each explanatory variable that weigh each characteristic by its effect on the individual variance term.  Maximum Likelihood estimation is used to estimate this model by specifying the following log-likelihood function for the normal distribution

$$\log L = \frac{n}{2}\log 2\pi - \frac{1}{2}\sum_{i=1}^{n}\left[\log\left(\sigma^2\right) + \mathbf{x}_i{}'\alpha\right] + \frac{1}{2}\sum_{i=1}^{n}\sigma^2 \frac{\varepsilon_i^2}{\exp(\mathbf{x}_i{}'\alpha)} \; . \tag{6}$$

Note that the variance is no longer assumed to be constant across observations, but rather depends on the explanatory variables, $\mathbf{x}_i$.

From equations 4 and 5, the expected conditional mean and conditional variance of each yield variable can be calculated at each observation. These values provide a description of the risk associated with each variable faced by cattle feeders at the time cattle are placed on feed. These values can subsequently be incorporated into an estimate of *ex-ante* expected profits, which is also dependent on expected means and expected variances for feed costs and fed cattle prices. This provides not only an estimate of the overall expected variability in profits prior to placing cattle on feed, but also the impact of individual factors such as prices and yield on expected profits and profit variability.

## Data

The empirical analysis is applied to a comprehensive set of data collected from five cattle feedlots located in Kansas and Nebraska. Proprietary production and cost data were obtained for 11,397 pens of cattle from 1995 to 2004. Table 1 contains the summary statistics from the data sample. Dry Matter Feed Conversion (*DMFC*) measures the pounds of dry feed required per pound of live weight gain and the average *DMFC* is calculated by dividing total dry feed used by total weight gained in the pen during the feeding cycle. Veterinary costs per head (*VCPH*) are calculated by dividing the total dollar amount spent on veterinary services by the pen size. Mortality rate (*MORT*) is a percentage calculated as the number of death losses during the feeding period divided by the number of head initially placed on feed. The size of a pen of cattle averaged 134 head with an average placement weight of 737.5 pounds and an average finished weight of 1,178 pounds. *In-Weight* is measured as the average weight per head in each pen upon placement on feed.[2] The log of *In-Weight* is used in each of the three models. To capture seasonal effects, placement dates are measured using binary variables denoting *Winter*, *Spring*, *Summer*, and *Fall* placement.[3] Binary variables are also used to differentiate pens by gender (*Steers*, *Heifers*, *Mixed*) and feedlot location (*KS* and *NE*).

## Estimation Results

*Dry Matter Feed Conversion Model*

Table 2 shows the conditional mean Maximum Likelihood estimation (MLE) results of Harvey's Model for equation 1. The use of MLE to obtain parameter estimates for *DMFC* requires the assumption of a parametric distribution for the error terms. After conditioning out the deterministic factors, *DFMC* appears to be most closely characterized with a log-normal distribution. This is reflected in a substantial degree of positive skewness in the distribution of residuals from an initial regression of *DFMC* on the conditioning variables. Therefore, a normal likelihood function is used, where the dependent variable is the log of *DMFC*.

The signs of the coefficients for *Steers* and *Mixed* pens indicate that heifers have higher *DMFC* rates than the other two types of pens. This suggests that pens of all heifers are less efficient at feed conversion overall than either pens of steers or pens with a combination of both sexes.

Parameter estimates for the *KS* binary variable indicate that *DFMC* is significantly lower for the two Kansas feedlots, relative to the Nebraska feedlots. This difference in feed efficiency may be a result of differences in management practices between the two states. For example, Nebraska pens in our sample typically have lower placement weights and higher fed weights, resulting in an additional 25 days on feed.

Mean differences in conditioning variables between the two states are summarized in table 3.

The coefficient for the log of *In-Weight* (*Inwtlog*) is positive, indicating that higher placement weights decrease feed efficiency (i.e., require higher feed conversion rates). Specifically, a 10% increase in average *In-Weight*, will correlate with a 1.9% increase in *DMFC*. This finding is supported by previous literature (Schroeder, et al. 1993; Mark, Schroeder, and Jones 2000), which suggests that heavier placement weight cattle have a higher DMFC rate (i.e., they are less efficient at feed conversion) than lighter placement weight cattle.

According to Mark and Schroeder (2002), optimal cattle performance typically occurs within a temperature range of 40 to 60 degrees Fahrenheit. Temperatures outside of this range reduce cattle feeding performance. Specifically, higher temperatures lead to declined weight gain from lower feed consumption, while colder temperatures increase maintenance energy, leading to higher conversion rates. Increased variability in weather and precipitation can also reduce performance. The *Summer* binary variable was omitted from the model, therefore the signs of the other seasonal variables are interpreted relative to a summer placement. The coefficient for *Winter* is not significantly different from *Summer*. Since both months are outside of the range of optimal feeding, cattle may perform just as well in the hot summer as in the colder winter, although for different reasons. *Spring*, which has average monthly temperatures well within the range of optimal feeding, has a significant negative coefficient. This implies that if a cattle feeder is given the choice between starting a pen of cattle in the spring as opposed to summer, it is possible to decrease DMFC by placing them on feed in the spring. Pens in this data set averaged nearly 129 days on feed, implying that most observations straddle two different seasons. The parameter estimate for *Fall* is significantly positive, meaning cattle entering during fall are the less efficient at feed conversion. However, the *Fall* binary variable includes fall and winter months, during which extreme temperature and precipitation conditions can occur in both Kansas and Nebraska. This may cause *DMFC* to be higher than in any other season.

Table 2 also includes the conditional variance MLE results for *DMFC*. Equation 5 describes the linear equation used to estimate these variances by observation. The heteroskedasticity parameter estimates offer insight into how the conditioning variables affect the conditional variance. *Inwtlog* has a significant positive correlation with higher variance in *DMFC*. *Mixed* pens present the highest variance by gender, followed by *Heifers* and *Steers*. There is not a significant difference between *Winter* and *Summer*, while *Fall* and *Spring* both present significant differences in individual variability when compared to *Summer*.

*Mortality Rate Model*

Table 4 contains the conditional mean MLE results for the model described in equation 2, where mortality rate (*MORT*) is the dependent variable. The coefficients for *Steers* and *Mixed* indicate that both types of pens have higher mortality rates, relative to pens consisting of heifers only. The coefficient for *KS* indicates that there is not a statistically significant difference in mortality rates between Kansas and Nebraska feedlots. The negative coefficient for *Inwtlog* suggests that higher placement weight cattle have lower mortality rates than lower placement weight cattle. While the coefficient for *Winter i*s not statistically different from the base season of *Summer*, the coefficients for *Fall* and

*Spring* indicate that mortality rates are higher for fall placement cattle and lower for spring placement cattle, as compared a summer placement date.

The conditional variance of *MORT* is described by the heteroskedasticity parameters listed in Table 4. All the conditioning variables in the model have a statistically significant effect on the conditional variance of mortality rate. Pens consisting of steers only have a negative impact on the conditional variance of mortality rate, while pens of mixed gender have a higher conditional variance when compared to pens of heifers only. The coefficient for *KS* indicates that the conditional variance of mortality rate is higher for Kansas feedlots, relative to Nebraska feedlots. The conditional variance of mortality rate is lower for higher placement weight cattle, as indicated by the negative coefficient for *Inwtlog*. The seasonal variables indicate a lower conditional variance for winter and spring placement and a higher variance of mortality rate for fall placement, as compared to summer placement.

*Veterinary Costs Model*

Table 5 shows MLE results for the conditional mean model described by equation 3, where the dependent variable is veterinary costs per head of cattle (*VCPH*). As with the *DFMC* model, *VCPH* appears to be most closely characterized with a log-normal distribution. Therefore, the model is estimated using the log of *VCPH* as the dependent variable.

The coefficients for *Steers* and *Mixed* indicate that *VCPH* are higher for these pens, as compared to pens of heifers. *VCPH* is a proxy for the general health of a pen of cattle. Therefore, higher veterinary costs indicate poorer overall health of pens of steers and mixed gender when compared to pens of heifers.

Feedlots in Kansas appear to have lower *VCPH*, as compared to Nebraska feedlots. Lower spending on veterinary services per head may be due to differences in management practices or a higher average of days on feed in Nebraska feedlots. The sign of the coefficient for *Inwtlog* indicates that higher placement weight cattle appear to have lower *VCPH*. Since both *VCPH* and *MORT* essentially provide an inverse measure of yield, this result is consistent with the results of the mortality rate model where higher placement weight cattle have fewer health problems than lower placement weight cattle.

The coefficients of seasonal binary variables for *Winter* and *Spring* indicate lower *VCPH*, as compared to summer placement dates. The coefficient for *Fall* was not statistically different from *Summer*.

The heteroskedasticity parameters listed in Table 5 describe the conditional variance of *VCPH*. All the conditioning variables in the model had a statistically significant effect on the conditional variance of *VCPH*. Pens consisting of steers only and mixed gender both have a negative impact on the conditional variance of *VCPH*, as compared to pens of heifers only. The coefficient for *KS* indicates that the conditional variance of *VCPH* is higher for Kansas feedlots, relative to Nebraska feedlots. Similar to the results for mortality rate, the conditional variance of *VCPH* is lower for higher placement weight cattle, as indicated by the negative coefficient for *Inwtlog*. The seasonal variables indicate a higher conditional variance for all placement dates, relative to summer placement.

**Profitability of Cattle Feeding**

The conditional expected mean and variance of each of the yield factors describes the volatility of DMFC, mortality rate, and veterinary costs after accounting for information known prior to placing cattle on feed. These estimates can be combined with conditional expected means and variances for corn prices and fed cattle prices to characterize the conditional profitability risk of cattle feeding. By analyzing profit risk in this manner, feedlot owners and others with a financial interest in cattle feeding can better understand not only the overall profitability risks they face, but also the contributions of individual yield and price volatilities to that risk.

In order to implement these risk models in a broader consideration of the *ex-ante* risks associated with cattle feeding profitability, measures of the conditional variability of feed prices and the price of the finished commodity—fed cattle—are needed. Measures of the expected future price of corn (an important indicator of feed prices) and fed-cattle prices are available in futures markets. In addition, options contracts offer market-based measures of the conditional variability of expected future prices. The futures and options contracts corresponding to the placement dates and the dates of finishing are used in the profit model.

Within the context of our yield model for cattle feeding, five random variables are relevant as sources of profit risk—DMFC, mortality rate, veterinary costs—all variables modeled using the conditional mean and heteroskedasticity models discussed above—and corn and fed cattle future and options prices. The standard Black-Scholes assumption of log-normality is used to derive distributional aspects of corn and fed cattle prices from the implied volatilities taken from options markets. The models of the three random yield variables, taken together with the log-normally distributed corn and fed cattle prices, allow us to derive an expression for the expected level of profits associated with any particular placement. The profit estimates are conditioned on the conditioning factors relevant to the yield factors as well as on expected prices, represented by the futures prices pertinent to the contract corresponding to the feeding period.

Simulations were conducted based upon the five-variable risk model. For a given set of conditioning variables, the conditional heteroskedasticity models are used to predict the conditional means and variances associated with each yield factor. Although the variance terms are allowed to vary with the conditioning factors, the covariance terms are held fixed at the values implied by estimates from the overall sample (based on model residuals). Zero correlation is assumed between the three pen-level yield factors, corn prices, and fed cattle prices. It is well-recognized that rank correlation is preserved by any monotonic transformation of random variables. Therefore, draws from a multivariate normal distribution can be used to generate correlated values with means and variances specified by the modeling framework for each of the five random variables. For each realization of correlated variables, a profit realization is calculated. From a large number of simulated profit realizations (100,000 correlated random draws are used from the five variable system), it is possible to assess the distributional properties associated with expected profits.

Distributions for profit per head were simulated using the following scenario: a pen of steers placed on feed in a Kansas feedlot on May 30, 2006. The expected fed cattle price ($84.48/cwt) and expected corn price ($2.54/bu) were taken from futures contract prices for the contract ending October 2006 and July 2006, respectively. The

October contract date was used for fed cattle to reflect the expected selling date, given that the cattle are fed for five months. Since the feed cost is incurred throughout the five month period, the July corn contract is used as a proxy for the average price of corn over the entire feeding period. The mean value of each conditioning variable is used in the models for *DMFC*, *MORT*, and *VCPH*. To illustrate the effect on profit per head from changes in the variability of fed cattle prices and corn prices, three separate simulations were run within the profit model. The first simulation held variance at its average level (20%), and then variance was adjusted to simulate a high risk scenario (24%) and a low risk scenario (16%). Figures 1 and 2 illustrate the three simulations for fed cattle and corn prices, respectively.

The simulation indicates increases in live cattle price variance leads to a significantly wider distribution of profits, while the effect from corn price variability is much less noticeable. The mean values of profit per head remained mostly unaffected by live cattle price variability; however the standard deviation of profit was significantly increased. In this particular simulation, the high and low risk scenarios for live cattle prices changed the first quartile of profits by $52.50 per head.

## Conclusion

Recent legislation mandating the development of new insurance products for livestock necessitates a careful consideration of the effects on profitability risk from not only input and output prices, but also cattle yields. While other studies of cattle feeding profitability have used feed conversion as a measure of yield, this study also explicitly considers the effects of overall cattle health on yield.

Multiplicative heteroskedasticity models were estimated for each of the three yield measures; DMFC, mortality rate, and veterinary costs. Each model was constructed using conditioning variables, which reflect information known to a cattle feeder prior to placement of a pen of cattle on feed. The model estimates provide more insight into the relative impact of the conditional variables on both the expected mean and variance of each measure of yield. The results of the DMFC model indicate statistically significant differences between gender, season, and feedlot location on feeding efficiency. The coefficient of placement weight suggests that heavier weight cattle are less efficient at feed conversion than lighter weight cattle. Results from the mortality rate and veterinary cost models suggest that higher placement weight cattle have lower veterinary costs and mortality rates, suggesting that higher placement weight cattle may have fewer health problems than lower placement weight cattle.

Profitability risk is impacted by fed cattle prices, feed costs, and yield. Therefore, to arrive at an *ex-ante* estimate of the distribution of profits, the profit risk model must include all these sources of risk. Initial simulations using high and low variability in both fed cattle prices and corn prices indicate that fed cattle price has a much larger impact on the overall variability of profit per head than corn prices.

Several aspects of the data and modeling can be re-examined for future research. First, not every pen of cattle suffered a mortality loss, so the value for mortality rate is equal to zero for approximately 46 percent of the observations in the data. Therefore, it may be more accurate to estimate mortality risk using a Tobit model that would still allow for heteroskedasticity. Second, the data includes a very large number of observations, which may make estimation of semi-parametric and nonparametric models of risk possible.  Rather than imposing the log-normal or normal distribution on the yield measures, the data would determine the closest fitting distribution for characterizing cattle yield risk.

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**Footnotes**

[1] This is known as the model selection problem.

[2] Pens with average placement weights below 500 pounds and above 900 pounds were excluded from our sample.

[3] Seasons are split into *Winter* (Dec-Feb), *Spring* (Mar-May), *Summer* (Jun-Aug), and *Fall* (Sep-Nov).

**Table 1. Variable Descriptions and Summary Statistics**

| Variable Name | Description | Mean | Standard Deviation | Minimum Value | Maximum Value |
|---|---|---|---|---|---|
| *DMFC* | Dry matter feed conversion | 6.19 | 0.72 | 4 | 24 |
| *VCPH* | Veterinary cost per head | 11.83 | 6.25 | 0 | 60 |
| *MORT* | Mortality loss rate | 0.93 | 1.53 | 0.00 | 25.83 |
| *InWeight* | Average weight per head of cattle for the entire pen measured upon entrance | 737.50 | 87.22 | 500 | 900.00 |
| *OutWeight* | Average weight per head of cattle for the entire pen measured upon exit | 1,177.91 | 88.10 | 910 | 1472 |
| *Winter* | Binary variable equal to 1 if entry was between Dec - Feb | 0.25 | 0.44 | 0 | 1 |
| *Spring* | Binary variable equal to 1 if entry was between Mar - May | 0.23 | 0.42 | 0 | 1 |
| *Summer* | Binary variable equal to 1 if entry was between Jun - Aug | 0.26 | 0.44 | 0 | 1 |
| *Fall* | Binary variable equal to 1 if entry was between Sep - Nov | 0.25 | 0.43 | 0 | 1 |
| *Steers* | Binary variable equal to 1 if entire pen of cattle were Steers | 0.51 | 0.50 | 0 | 1 |
| *Heifers* | Binary variable equal to 1 if entire pen of cattle were Heifers | 0.37 | 0.48 | 0 | 1 |
| *Mixed* | Binary variable equal to 1 if pen was mixed gender | 0.12 | 0.33 | 0 | 1 |
| *KS* | Binary variable equal to 1 if Kansas feedlot location | 0.80 | 0.40 | 0 | 1 |
| *NE* | Binary variable equatl to 1 if Nebraska feedlot location | 0.20 | 0.40 | 0 | 1 |

Total sample size n=11,397

**Table 2. Harvey's Model Results for DMFC**

**Conditional Mean**

| Variables | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 0.6983 | 0.0489 | 14.2900 | <.0001 |
| *Steers* | -0.0696 | 0.0019 | -37.2400 | <.0001 |
| *Mixed* | -0.0277 | 0.0035 | -7.8600 | <.0001 |
| *KS* | -0.1228 | 0.0022 | -54.6100 | <.0001 |
| *Inwtlog* | 0.1891 | 0.0075 | 25.2300 | <.0001 |
| *Winter* | -0.0006 | 0.0024 | -0.2500 | 0.8048 |
| *Fall* | 0.0522 | 0.0027 | 19.6900 | <.0001 |
| *Spring* | -0.0168 | 0.0022 | -7.4800 | <.0001 |

**Conditional Variance**

| Variables | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 0.0107 | 0.0031 | 3.4900 | 0.0005 |
| *Steers* | -0.0596 | 0.0214 | -2.7800 | 0.0054 |
| *Mixed* | 0.4834 | 0.0260 | 18.5800 | <.0001 |
| *KS* | -0.1303 | 0.0265 | -4.9200 | <.0001 |
| *Inwtlog* | 0.6457 | 0.0873 | 7.4000 | <.0001 |
| *Winter* | 0.0211 | 0.0250 | 0.8400 | 0.3988 |
| *Fall* | 0.3550 | 0.0253 | 14.0400 | <.0001 |
| *Spring* | -0.3505 | 0.0272 | -12.9000 | <.0001 |

**Table 3. Comparison of Kansas and Nebraska Feedlots**

| Variable Name | Description | Kansas | Nebraska |
|---|---|---|---|
| *Obs* | Observations | 9,157 | 2,240 |
| *DMFC* | Dry Matter Feed Conversion | 6.04 | 6.79 |
| *VCPerHd* | Veterinary Cost Per Head | 11.34 | 13.85 |
| *Mortality* | Percentage of herd that die before slaughter | 0.929 | 0.952 |
| *InWt* | Average weight per head of cattle for the entire pen measured upon entrance | 741.6 | 720.8 |
| *OutWt* | Average weight per head of cattle for the entire pen measured upon exit | 1,171.9 | 1,202.6 |
| *DOFeed* | Days on Feed | 124.0 | 148.7 |

**Table 4. Harvey's Model Results for Mortality Rate**

**Conditional Mean**

| Variables | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 16.2077 | 1.0390 | 15.6000 | <.0001 |
| *Steers* | 0.0638 | 0.0343 | 1.8600 | 0.0626 |
| *Mixed* | 0.5872 | 0.0828 | 7.0900 | <.0001 |
| *KS* | 0.0317 | 0.0389 | 0.8100 | 0.4153 |
| *lnwtlog* | -2.3377 | 0.1572 | -14.8700 | <.0001 |
| *Winter* | -0.0153 | 0.0443 | -0.3500 | 0.7290 |
| *Fall* | 0.1315 | 0.0528 | 2.4900 | 0.0128 |
| *Spring* | -0.1204 | 0.0414 | -2.9100 | 0.0037 |

**Conditional Variance**

| Variables | HET Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 123,932.0000 | 20,039.0000 | 6.1800 | <.0001 |
| *Steers* | -0.0756 | 0.0115 | -6.5500 | <.0001 |
| *Mixed* | 0.9827 | 0.0184 | 53.3900 | <.0001 |
| *KS* | 0.1538 | 0.0144 | 10.6700 | <.0001 |
| *lnwtlog* | -3.5010 | 0.0490 | -71.5100 | <.0001 |
| *Winter* | -0.1153 | 0.0148 | -7.7700 | <.0001 |
| *Fall* | 0.3961 | 0.0145 | 27.3400 | <.0001 |
| *Spring* | -0.4257 | 0.0155 | -27.4600 | <.0001 |

**Table 5. Harvey's Model Results for Veterinary Costs**

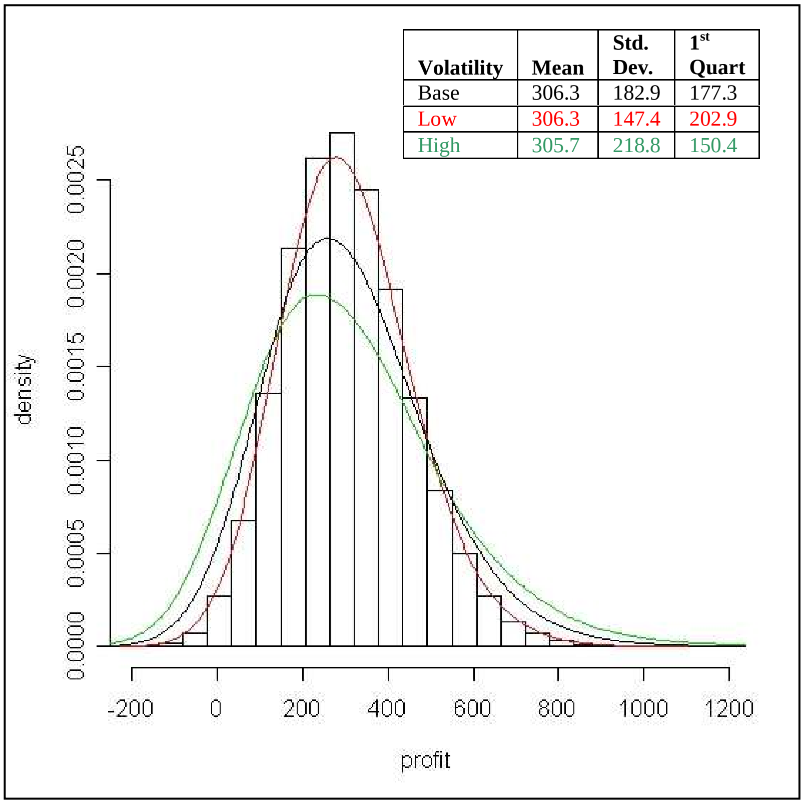
**Conditional Mean**

| Variables | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 10.7512 | 0.2139 | 50.2500 | <.0001 |
| *Steers* | 0.0650 | 0.0105 | 6.1800 | <.0001 |
| *Mixed* | 0.2211 | 0.0157 | 14.0500 | <.0001 |
| *KS* | -0.2217 | 0.0090 | -24.5200 | <.0001 |
| *lnwtlog* | -1.2481 | 0.0327 | -38.2200 | <.0001 |
| *Winter* | -0.0811 | 0.0102 | -7.9900 | <.0001 |
| *Fall* | 0.0040 | 0.0101 | 0.4000 | 0.6905 |
| *Spring* | -0.0798 | 0.0137 | -5.8100 | <.0001 |

**Conditional Variance**

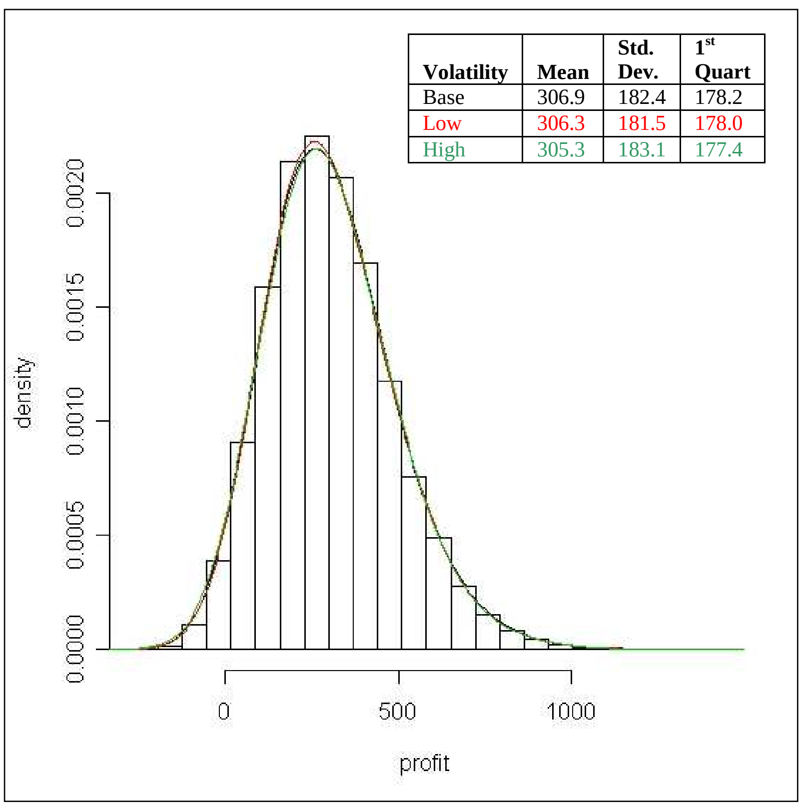
| Variables | HET Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| *Constant* | 36.6064 | 8.1629 | 4.4800 | <.0001 |
| *Steers* | -0.5877 | 0.0113 | -51.9700 | <.0001 |
| *Mixed* | -0.1160 | 0.0292 | -3.9800 | <.0001 |
| *KS* | 0.4627 | 0.0152 | 30.3900 | <.0001 |
| *lnwtlog* | -1.4064 | 0.0675 | -20.8400 | <.0001 |
| *Winter* | 0.3152 | 0.0159 | 19.8700 | <.0001 |
| *Fall* | 0.3369 | 0.0188 | 17.9600 | <.0001 |
| *Spring* | 0.5998 | 0.0148 | 40.5100 | <.0001 |

**Figure 1. Conditional Profits with varying levels of live cattle price volatility**




| Volatility | Mean | Std. Dev. | 1st Quart |
|---|---|---|---|
| Base | 306.3 | 182.9 | 177.3 |
| Low | 306.3 | 147.4 | 202.9 |
| High | 305.7 | 218.8 | 150.4 |

**Figure 2. Conditional Profits with varying levels of corn price volatility**




| Volatility | Mean | Std. Dev. | 1st Quart |
|---|---|---|---|
| Base | 306.9 | 182.4 | 178.2 |
| Low | 306.3 | 181.5 | 178.0 |
| High | 305.3 | 183.1 | 177.4 |