

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

**Eric J. Belasco**

Graduate Assistant  
North Carolina State University  
ejbelasc@ncsu.edu

**Mykel R. Taylor**

Graduate Assistant  
North Carolina State University  
mrtaylor@ncsu.edu

**Barry K. Goodwin**

Professor  
North Carolina State University  
bkgoodwi@ncsu.edu

**Ted C. Schroeder**

Professor  
Kansas State University  
tschroed@agecon.ksu.edu

*Selected Paper prepared for presentation at the  
NCSU Department of Agriculture and Resource Economics Seminar  
November 14, 2006*

*Copyright 2006 by Eric J. Belasco, Mykel R. Taylor, Barry K. Goodwin, and Ted C. Schroeder. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.*

## Abstract

The development of livestock insurance programs as part of the Agricultural Risk Protection Act of 2000 has fueled the need for further research evaluating the risks associated with fed cattle production. This research explicitly models yield risks related to feedlot operations through the use of maximum likelihood estimation, while controlling for multiplicative heteroskedasticity. The results demonstrate that pen characteristics, such as average entry weight, gender, season of placement, and location significantly influence the mean and variability of yield factors, defined as dry matter feed conversion, mortality, and animal health costs. Conditional ex-ante profit distributions are then derived through simulation methods, in order to evaluate the effects of shocks to prices or yields on the distributional characteristics of expected profits.

## **Introduction**

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 random components of risk. A straightforward example of conditioning factors is obvious in the case of crop yields—where yields 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.<sup>1</sup> 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

$$(1) \quad DMFC = f_1(\text{gender}, \text{location}, \text{in-weight}, \text{season})$$

$$(2) \quad MORT = f_2(\text{gender}, \text{location}, \text{in-weight}, \text{season})$$

$$(3) \quad VCPH = f_3(\text{gender}, \text{location}, \text{in-weight}, \text{season})$$

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;

*in-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 heteroskedastic 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 (iid) distributed. The model is specified as

$$(4) \quad y_i = \mathbf{x}_i' \boldsymbol{\beta} + \varepsilon_i$$

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 the individual characteristics of gender, feedlot location, entry weight, and season of placement used to explain the risk associated with each dependent variable (*DMFC*, *MORT*, *VCPH*). The conditional variance is unique for each observation and is estimated as

$$(5) \quad \sigma_i^2 = \sigma^2 \exp(\mathbf{z}_i' \boldsymbol{\alpha})$$

where  $\boldsymbol{\alpha}$  contains estimates for each explanatory variable that weigh each characteristic by its effect on the individual variance term and  $\mathbf{z}_i$  contains the conditioning variables that may affect the variance. In this model, the variables are the same as those contained in  $\mathbf{x}_i$ , but without the intercept term. Maximum Likelihood estimation is used to estimate

Harvey's model for *DMFC* and *VCPH* by specifying the following log-likelihood function for the normal distribution

$$(6) \quad \log L(\beta, \alpha, \sigma^2) = -\frac{n}{2} \log 2\pi - \frac{1}{2} \sum_{i=1}^n [\ln(\sigma^2) + \mathbf{z}'_i \alpha] - \frac{1}{2\sigma^2} \sum_{i=1}^n \frac{(y_i - \mathbf{x}'_i \beta)^2}{\exp(\mathbf{z}'_i \alpha)}.$$

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

Not every pen of cattle in the data set suffered a mortality loss, so the value for *MORT* is censored at zero for approximately 46 percent of the observations in the data. Therefore, the multiplicative heteroskedastic model for *MORT* is estimated as a Tobit model. Maximum Likelihood estimation is used to estimate Harvey's model for *MORT* by specifying the following log-likelihood function for the normal distribution

$$(7) \quad \log L(d_i | \beta, \alpha, \sigma^2) = \sum_{\forall d_i > 0} -\frac{1}{2} \left[ \log 2\pi + \ln(\sigma^2) + \mathbf{z}'_i \alpha + \frac{(y_i - \mathbf{x}'_i \beta)^2}{\sigma^2 \cdot \exp(\mathbf{z}'_i \alpha)} \right] + \sum_{\forall d_i = 0} \ln \left[ \Phi \left( \frac{-x'_i \beta_i}{\sigma^2 \exp(\mathbf{z}'_i \alpha)} \right) \right]$$

where  $\Phi$  is the normal CDF. The two parts of the likelihood function correspond to the Harvey's model for the non-limit observations (i.e. those with a positive death loss) and the relevant probabilities for the limit observations (i.e. those with zero death loss), respectively.

From equations 4 and 5, the expected conditional mean and conditional variance of each yield variable can be calculated for 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 a function of 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.<sup>2</sup> 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.<sup>3</sup> 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, *DMFC* 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 *DMFC* 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 *DMFC* 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* is 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 model profitability risk, a profit function must be used that accounts for the revenue and costs specific to cattle feeding. The expression for *ex-ante* profits on a per head basis is

$$(8) \quad \Pi = TR - FDRC - YC - FC - VC - IC$$

where  $\Pi$  are per head profits,  $TR$  is total revenue per head from cattle feeding,  $FDRC$  is the per head costs of purchasing feeder cattle,  $YC$  is the per head fixed cost (yardage cost) of feeding cattle,  $FC$  is the per head feed cost,  $VC$  are per head costs associated with veterinary care, and  $IC$  is an interest cost.  $TR$  is defined as

$$(9) \quad TR = FP \times CSW \times (1 - MORT) \times (0.96)$$

where  $FP$  is the price per hundred weight (\$/cwt) of fed cattle and  $CSW$  is the average sale weight of the finished cattle.  $TR$  is adjusted for death loss using the  $MORT$  variable and a standard 4% live-weight shrink is applied to reflect the expected loss in weight during transport from the feedlot to the packing plant.  $FDRC$  is defined as

$$(10) \quad FRC = FRP \times CPW$$

where  $FRP$  is the price per hundred weight of feeder cattle and  $CPW$  is the average weight of the feeder cattle at placement.  $YC$  is defined as

$$(11) \quad YC = (0.25) \times DOF$$

where  $DOF$  is the number of days the pen of cattle is in the feedlot and 0.25 is a typical per head day for feedlots in Kansas and Nebraska.  $FC$  is defined as

$$(12) \quad FC = CP \times \left\{ \frac{DMFC}{0.88} [CSW \times (1 - MORT) - CPW] \right\}$$

where  $CP$  is the price per bushel of corn and is multiplied by the corn-based feed ration, which is assumed to be 12% moisture.  $DMFC$  is adjusted to reflect the “as fed” feed conversion.  $IC$  is defined as

$$(13) \quad IC = \left\{ \frac{1}{2} [YC + FC + VC] + FRC \right\} \times DOF \times \frac{IR}{365}$$

where  $IR$  is the interest rate. This expression assumes that an interest charge is applied to the full amount of the feeder cattle cost,  $FRC$ , and half the total cost of yardage, feed, and veterinary fees. This assumption is based on the ability of cattle feeders to assess these charges throughout the feeding period, while the feeder cattle must be purchased at the beginning of the feeding period.

Within the context of our yield model for cattle feeding, five random variables are relevant as sources of profit risk. The three yield variables,  $DMFC$ , mortality rate, and veterinary costs, are modeled using the conditional mean and heteroskedasticity models discussed above. The other two variables are the conditional variability of feed prices and the price of the finished commodity, fed cattle. 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. Therefore, the futures and options contracts corresponding to the placement and finishing dates for a pen of cattle are used in the profit model.

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. The expected prices are represented by the futures price of the contract corresponding to the feeding period being considered. The expected mean of profits is a function of the variables described in expression (8), while the expected variance of profits is a function of the implied volatility of fed cattle and corn prices, and the variance of DMFC, MORT, and VCPH.

Simulations of profitability risk 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 distributional characteristics 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 residuals resulting from model estimates. Zero correlation is assumed between the three pen-level yield factors and the corn 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. Simulation of the three yield factors proceed following the method originally proposed by Fackler (1991). 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 are 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, assuming 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 annual interest rate was assumed to be 7.5 percent. The sample mean of each conditioning variable is used in the yield models to obtain an expected mean and variance 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. To illustrate a high, average, and low risk scenario for both corn and fed cattle prices, it was necessary to determine the amount of variability in those prices over the past 8 years. Using volatility data from the Chicago Board of Trade (CBOT) for corn prices and the Chicago Mercantile Exchange (CME) for fed cattle prices, the average volatility and standard deviation for corn and fed cattle prices was calculated. A high risk scenario was considered to be the average volatility plus one standard deviation, while the low risk scenario was considered to be the average minus one standard deviation. The first simulation held the fed cattle price variance at its average level (20%), and then adjusted to simulate a high risk scenario (26%) and a low risk scenario (14%). This simulation was repeated with the corn price variance adjusted to similar levels. Figures 1 illustrates the three simulations for fed cattle prices, while holding corn price at its average

volatility level and Figure 2 illustrates the simulation for corn price volatility, while holding fed cattle price constant at its average level.

The simulation results indicate that 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 \$78.40 per head.

## **Conclusion**

Recent legislation mandating the development of new insurance products for livestock requires 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 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 prices have 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, 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. Second, a multivariate model may more effectively account for the correlated relationship between the three yield factors.

## References

- Atwood, J., S. Shaik, and M. Watts. "Are Crop Yields Normally Distributed? A Reexamination." *American Journal of Agricultural Economics*. 85(2003):888-901.
- Chicago Board of Trade, Corn Quotes. 2006. Available at <http://www.cbot.com>, accessed.
- Chicago Mercantile Exchange, Live Cattle Futures. 2006. Available at <http://www.cme.com>, accessed.
- Coble, K.H., T.O. Knight, R.D. Pope, and J.R. Williams. "Modeling Farm Level Crop Insurance Demand with Panel Data." *American Journal of Agricultural Economics*. 78(1996):439-447.
- Fackler, P.L. "Modeling Interdependence: An Approach to Simulation and Elicitation." *American Journal of Agricultural Economics*. 73(1991):1091-1097.
- Gallagher, P. "U.S. Soybean Yields: Estimation and Forecasting with Nonsymmetric Disturbances." *American Journal of Agricultural Economics*. 69(1987):798-803.
- Goodwin, B.K., and A.P. Ker. "Modeling Price and Yield Risk." *A Comprehensive Assessment of the Role of Risk in U.S. Agriculture*. R.E. Just and R.D. Pope, eds., pp. 289-323. Boston: Kluwer Academic Press, 2002.
- Harvey, A.C. "Estimating Regression Models with Multiplicative Heteroscedasticity." *Econometrica*. 44(1976):461-465.
- Just, R.E. and Q. Weninger. "Are Crop Yields Normally Distributed?" *American Journal of Agricultural Economics*. 81(1999):287-304.
- Ker, Alan P. and Keith Coble. "Modeling Conditional Yield Densities." *American Journal of Agricultural Economics*. 85(2003):291-304.
- Ker, A. P. and B. K. Goodwin. "Nonparametric Estimation of Crop Insurance Rates Revisited." *American Journal of Agricultural Economics*. 83(2000):463-478.
- Langemeier, M.R., T.C. Schroeder, and J. Mintert. "Determinants of Cattle Finishing Profitability." *Southern Journal of Agricultural Economics* 24(1992):41-48.
- Lawrence, J.D., Z. Wang, and D. Loy. "Elements of Cattle Feeding Profitability in Midwest Feedlots." *Journal of Agricultural and Applied Economics* 31(1999):349- 357.
- Mark, D.R., and T.C. Schroeder. *Effects of Weather on Average Daily Gain and*

- Profitability*. Cattlemen's Day Report of Progress No. 890, Kansas Agricultural Experiment Station, March 2002.
- Mark, D.R., T.C. Schroeder, and R. Jones. "Identifying Economic Risk in Cattle Feeding." *Journal of Agribusiness* 18(2000):331-344.
- Nelson, C.H. "The influence of Distribution Assumptions on the Calculation of Crop Insurance Premia." *North Central Journal of Agricultural Economics*. 12(1990):71-78.
- Nelson, C.H. and P.V. Preckel. "The Conditional Beta Distribution as a Stochastic Production Function." *American Journal of Agricultural Economics*. 71(1989):370-378.
- Ramirez, O.A., S. Misra, and J. Field. "Crop-Yield Distributions Revisited." *American Journal of Agricultural Economics*. 85(2003):108-120.
- Schroeder, T.C., M.L. Albright, M.R. Langemeier, and J. Mintert. "Factors Affecting Cattle Feeding Profitability." *Journal of the American Society of Farm Managers and Rural Appraisers*. 57(1993):48-54.
- Sherrick, B.J., F.C. Zanini, F.D. Schnitkey, and S.H. Irwin. "Crop Insurance Valuation under Alternative Yield Distributions." *American Journal of Agricultural Economics*. 86(2004): 406-419.

## Footnotes

<sup>1</sup> This is known as the model selection problem.

<sup>2</sup> Pens with average placement weights below 500 pounds and above 900 pounds were excluded from our sample.

<sup>3</sup> 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
<i>DMFC</i>	Dry matter feed conversion	6.19	0.72	4	24
<i>VCPH</i>	Veterinary cost per head	11.83	6.25	0	60
<i>MORT</i>	Mortality loss rate	0.93	1.53	0.00	25.83
<i>InWeight</i>	Average weight per head of cattle for the entire pen measured upon entrance	737.50	87.22	500	900.00
<i>OutWeight</i>	Average weight per head of cattle for the entire pen measured upon exit	1,177.91	88.10	910	1472
<i>Winter</i>	Binary variable equal to 1 if entry was between Dec - Feb	0.25	0.44	0	1
<i>Spring</i>	Binary variable equal to 1 if entry was between Mar - May	0.23	0.42	0	1
<i>Summer</i>	Binary variable equal to 1 if entry was between Jun - Aug	0.26	0.44	0	1
<i>Fall</i>	Binary variable equal to 1 if entry was between Sep - Nov	0.25	0.43	0	1
<i>Steers</i>	Binary variable equal to 1 if entire pen of cattle were Steers	0.51	0.50	0	1
<i>Heifers</i>	Binary variable equal to 1 if entire pen of cattle were Heifers	0.37	0.48	0	1
<i>Mixed</i>	Binary variable equal to 1 if pen was mixed gender	0.12	0.33	0	1
<i>KS</i>	Binary variable equal to 1 if Kansas feedlot location	0.80	0.40	0	1
<i>NE</i>	Binary variable equal 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**

<b>Conditional Mean</b>				
Variables	Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	0.6983	0.0489	14.2900	<.0001
<i>Steers</i>	-0.0696	0.0019	-37.2400	<.0001
<i>Mixed</i>	-0.0277	0.0035	-7.8600	<.0001
<i>KS</i>	-0.1228	0.0022	-54.6100	<.0001
<i>Inwtlog</i>	0.1891	0.0075	25.2300	<.0001
<i>Winter</i>	-0.0006	0.0024	-0.2500	0.8048
<i>Fall</i>	0.0522	0.0027	19.6900	<.0001
<i>Spring</i>	-0.0168	0.0022	-7.4800	<.0001
<b>Conditional Variance</b>				
Variables	Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	0.0107	0.0031	3.4900	0.0005
<i>Steers</i>	-0.0596	0.0214	-2.7800	0.0054
<i>Mixed</i>	0.4834	0.0260	18.5800	<.0001
<i>KS</i>	-0.1303	0.0265	-4.9200	<.0001
<i>Inwtlog</i>	0.6457	0.0873	7.4000	<.0001
<i>Winter</i>	0.0211	0.0250	0.8400	0.3988
<i>Fall</i>	0.3550	0.0253	14.0400	<.0001
<i>Spring</i>	-0.3505	0.0272	-12.9000	<.0001

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

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

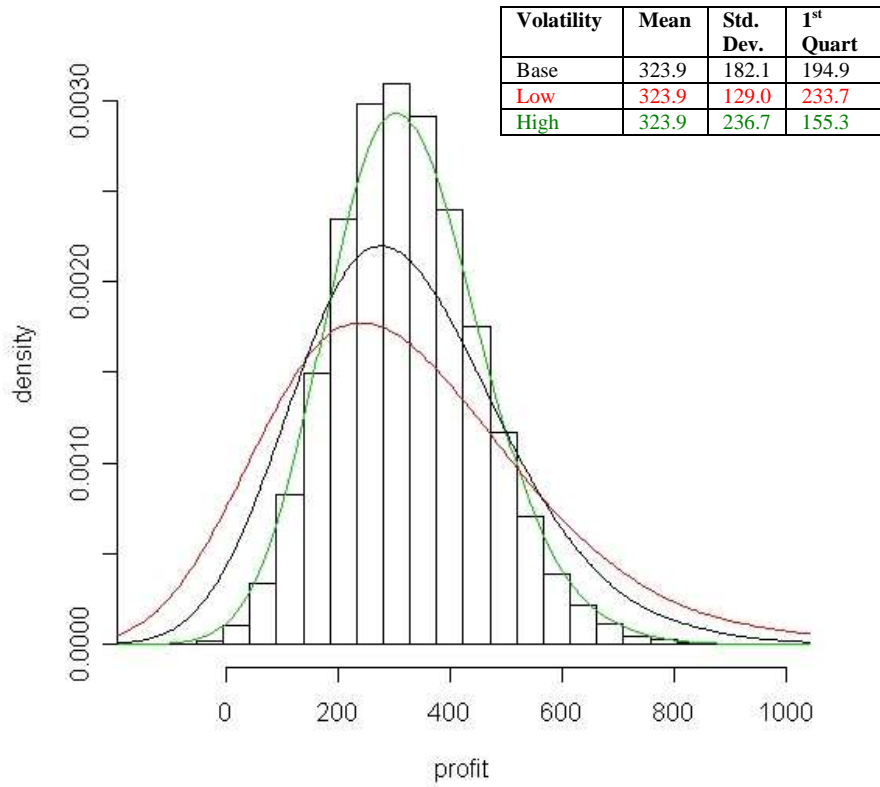
**Table 4. Harvey's Model Results for Mortality Rate**

<b>Conditional Mean</b>				
Variables	Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	24.2919	1.3859	17.5300	<.0001
<i>Steers</i>	0.1872	0.0507	3.6900	0.0002
<i>Mixed</i>	0.4404	0.1011	4.3600	<.0001
<i>KS</i>	-0.1035	0.0528	-1.9600	0.0502
<i>Inwtlog</i>	-3.6660	0.2114	-17.3400	<.0001
<i>Winter</i>	0.0649	0.0618	1.0500	0.2931
<i>Fall</i>	0.0616	0.0697	0.8800	0.3767
<i>Spring</i>	-0.0792	0.0624	-1.2700	0.2042
<b>Conditional Variance</b>				
Variables	HET Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	450.5199	207.5118	2.1700	0.0299
<i>Steers</i>	-0.0583	0.0428	-1.3600	0.1740
<i>Mixed</i>	0.8158	0.0616	13.2400	<.0001
<i>KS</i>	0.2139	0.0492	4.3500	<.0001
<i>Inwtlog</i>	-1.6577	0.1417	-11.7000	<.0001
<i>Winter</i>	-0.1930	0.0539	-3.5800	0.0003
<i>Fall</i>	0.2745	0.0533	5.1500	<.0001
<i>Spring</i>	-0.3171	0.0582	-5.4500	<.0001

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

<b>Conditional Mean</b>				
Variables	Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	10.7512	0.2139	50.2500	<.0001
<i>Steers</i>	0.0650	0.0105	6.1800	<.0001
<i>Mixed</i>	0.2211	0.0157	14.0500	<.0001
<i>KS</i>	-0.2217	0.0090	-24.5200	<.0001
<i>Inwtlog</i>	-1.2481	0.0327	-38.2200	<.0001
<i>Winter</i>	-0.0811	0.0102	-7.9900	<.0001
<i>Fall</i>	0.0040	0.0101	0.4000	0.6905
<i>Spring</i>	-0.0798	0.0137	-5.8100	<.0001
<b>Conditional Variance</b>				
Variables	HET Parameter Estimate	Standard Error	t-statistic	p-value
<i>Constant</i>	36.6064	8.1629	4.4800	<.0001
<i>Steers</i>	-0.5877	0.0113	-51.9700	<.0001
<i>Mixed</i>	-0.1160	0.0292	-3.9800	<.0001
<i>KS</i>	0.4627	0.0152	30.3900	<.0001
<i>Inwtlog</i>	-1.4064	0.0675	-20.8400	<.0001
<i>Winter</i>	0.3152	0.0159	19.8700	<.0001
<i>Fall</i>	0.3369	0.0188	17.9600	<.0001
<i>Spring</i>	0.5998	0.0148	40.5100	<.0001

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



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

