The *Cattle Feeding Return Risk Analyzer©*: A Risk Assessment Tool for Cattle Feeders

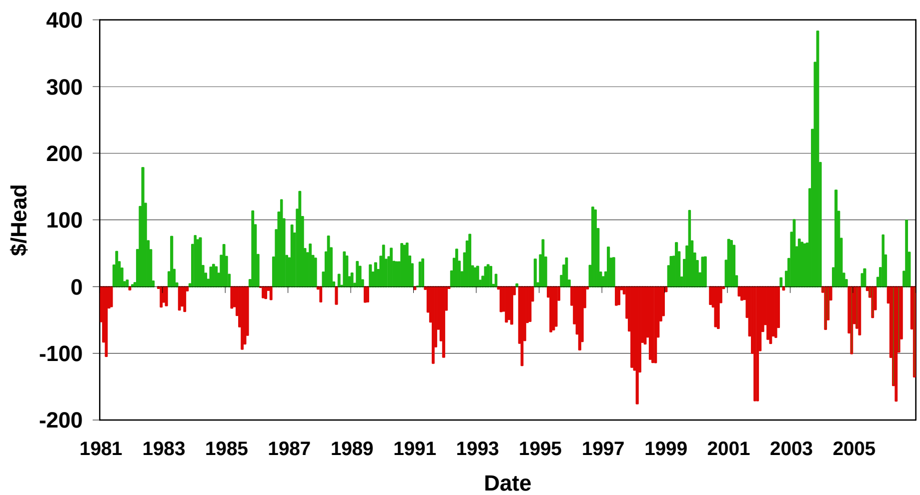
http://www.naiber.org/cattleriskanalyzer/

1. Introduction

Cattle feeding is a risky venture. Cattle feeding returns often oscillate from lucrative profits to substantial losses over short time periods. Figure 1 illustrates monthly average net returns for feeding cattle in Kansas from 1981 through 2006. Wide swings in net returns as well as periods of sustained losses are apparent. For example, during the first few months of 2001, cattle feeders were making about $70 per head. However, by November of that year they were losing over $170 per head and these losses were sustained for 16 consecutive months, only to be followed by record profits a few months later, reaching over $300 per head in late 2003. Clearly, both inter-year and intra-year cattle feeding return risks are substantial.

Even more striking is the fact that variability in net returns to feeding cattle has nearly doubled in recent years, with the standard deviation of $60 per head from 1990-1999 increasing to $96 per head from 2000-2006. For the entire industry, this increased risk per head multiplied by the approximately 28 million head of fed cattle marketed annually amounts to about $1 billion[1] greater risk facing cattle feeders annually in the decade of the 2000s in comparison to the 1990s. This risk arises from a wide array of sources, including feeder and fed cattle prices, feed and other operating costs, and production (yield) risks associated with feeding efficiency, disease, and other factors affecting feeding performance. Cattle feeders need improved assessment and measurement tools to better understand the magnitude and sources of risk as well as anticipate and ultimately effectively manage return risk.

Figure 1. Estimated Monthly Cattle Feeding Returns 1981- 2006



*Source: Jones, R. Kansas State University Research & Extension

[1] Calculated by multiplying 28 million head times ($96/head standard deviation minus $60/head standard deviation).

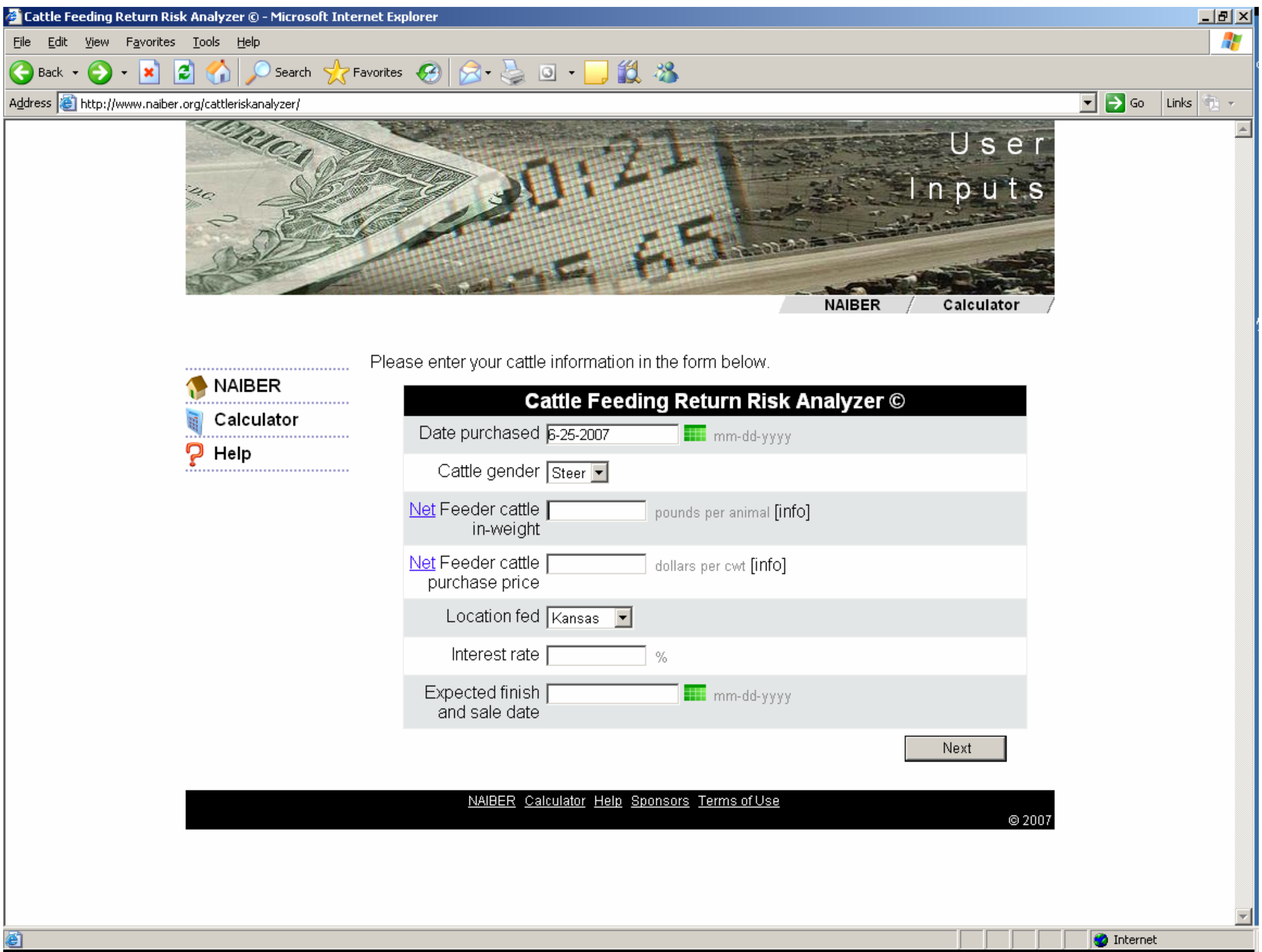
2. Purpose of the Risk Analyzer

The *Cattle Feeding Return Risk Analyzer*© was designed to provide a market-based, research-grounded estimate of the risk facing cattle feeders who are placing cattle on feed. The computer-based tool is intended to enhance cattle feeder ability to identify the sources of risk and to comprehend the nature of the financial risks associated with cattle feeding. In addition, the tool should be useful to other individuals with a stake in risk associated with fed cattle production, including lenders, management consultants, and input suppliers.

3. Using and Interpreting the Risk Analyzer

The risk calculator is publicly available at: *http://www.naiber.org/cattleriskanalyzer/*

When you open the web page, the first page of the calculator looks like the diagram below.



STEP I: USER INPUTS

The first step in using the calculator involves the input of a number of variables that describe the feeding situation of interest to the user. The following variables must be specified:

1. **Date purchased** - the date feeder cattle are purchased. The default date is always set to the current date. If you want to go forward or backward in time to pick a different purchase date, you can do so by selecting an alternative purchase date from the pop-up calendar. However, the purchase date selected does not affect the expected cattle or corn prices or their associated volatility as these are always established using the most recent information available from the previous day's futures settlement prices (see Calculations section later for details). In particular, the calculator downloads the relevant price data from commodity futures exchanges each night and has it available for use the following day.

2. **Cattle gender.** Next you select from the drop down menu whether the cattle are steers or heifers. The calculator is only parameterized for steers or heifers and not for mixed pens.

3. **Net Feeder cattle in-weight.** Here the user inputs the estimated average weight of the feeder cattle after shrinkage to the finishing feedlot in pounds per head. Users can click on the Net word where a reminder is displayed that this is a shrunken weight.

4. **Net Feeder cattle purchase price.** Enter the price paid for the feeder cattle in $ per hundred weight inclusive of freight to the feedlot. So, this should be the price per pound paid plus relevant freight costs.

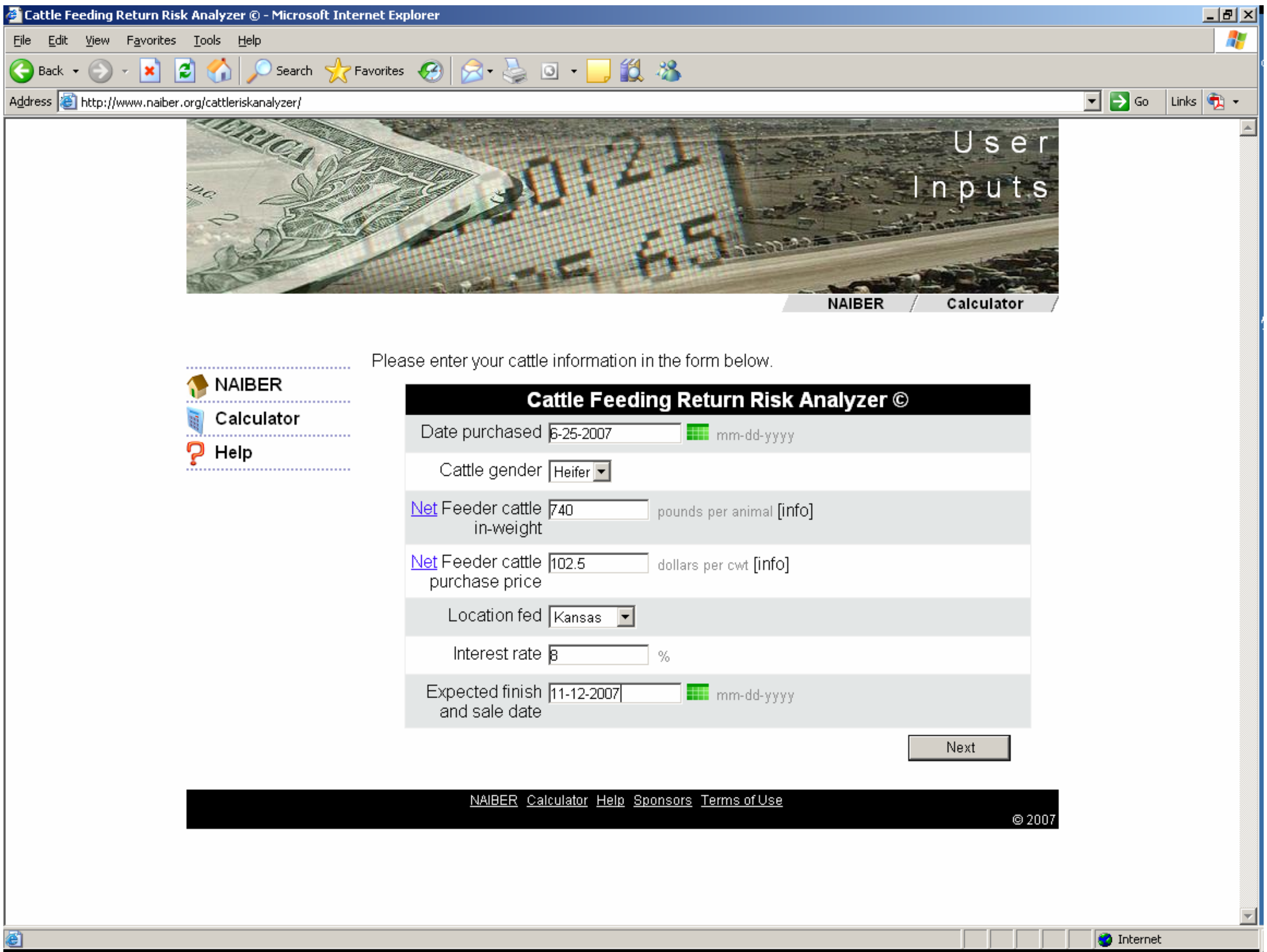
5. **Location Fed.** Currently, the calculator is parameterized for cattle fed in either Kansas or Nebraska. If you are feeding in another location, be aware conditions are likely different so select the location that best matches your location.

6. **Interest rate.** This should be the interest rate you currently pay for cattle feeding or similar operating loan in annual percentage rate.

7. **Expected finish and sale date.** Select the date you expect the cattle to finish and be marketed as fed cattle.

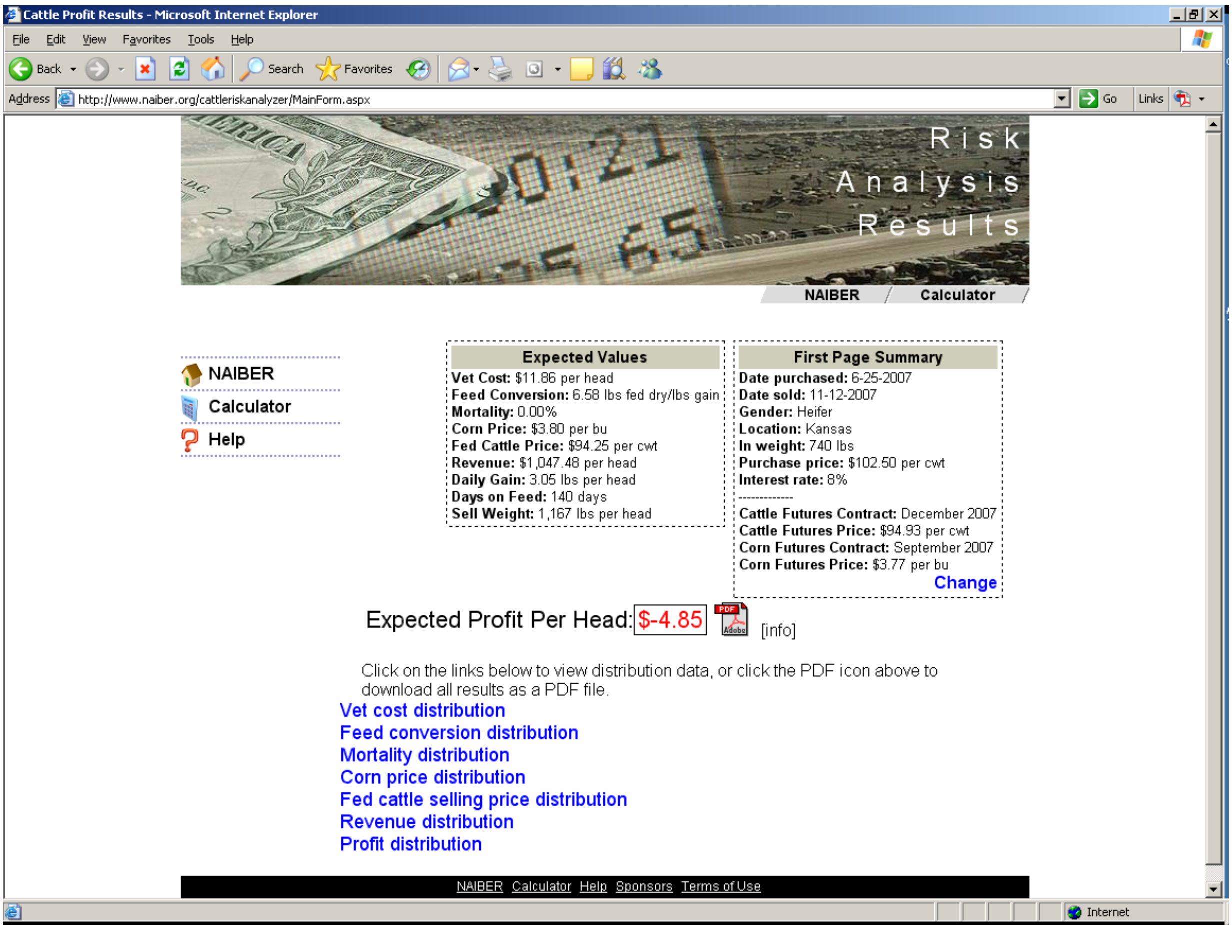
These are all the inputs you need to start the tool. You will be able to come back and modify any of these if you wish in the next step. In fact, such modification allows users to consider "what-ifs" that can illuminate the sensitivity of their profits and risks to changes in underlying feeding conditions.

Suppose you had a pen of 740 pound heifers bought on June 25, 2007 at net price of $102.50/cwt net of transportation to the feedlot. You are feeding the cattle in Kansas. Your interest rate on borrowed funds is 8% at an annual rate. You expect to finish these cattle on November 12, 2007 (after 140 days on feed). The input screen would look like:



At this point you click the "Next" button which after a few seconds delay (due to the underlying calculations which are being executed) reveals the overall results screen below:

IMPORTANT: You will not be able to exactly replicate every part of this example because the results reflect market conditions as of June 25, 2007. The calculator automatically brings in the latest (yesterday's) fed cattle and corn futures and options market prices into the expected values calculations each time.



STEP II: RESULTS OUTPUT

The inputs that you entered are summarized in the box labeled "First Page Summary". For sensitivity analysis involving other alternatives or for correcting a mistake you can hit the "Change" link in that box which will navigate you back to the first page again to modify the input. Also contained in the input box are the associated cattle futures contract and price (previous day's settlement price) and corn futures contract and associated price (previous day's settlement price) for the relevant contracts. The cattle futures contract is the contract month that expires most closely to, but not before, the finish date you indicated. In this example, you indicated a November finish date, which corresponds to the nearby contract being December live cattle futures. The corn contract used is the contract in the middle of the feeding period. In this case you would have cattle on feed during June-July-August-September. The corn contract that would expire soonest after 70 days after June 25th (i.e., September 3rd) would be the September contract. The cattle futures and corn futures prices quoted are the last trading day's settlement prices. More details are present in the Calculations section below. The cattle and corn futures prices adjusted for local expected basis serve as the expected corn and selling prices for the fed cattle.

The box in the middle labeled "Expected Values" presents calculations based on parameters estimated and relationships in the Analyzer. "Vet Cost" is the expected cost of medications and veterinary expenses per head for these animals. "Feed Conversion" is the expected dry matter feed conversion (lbs. dry matter fed per lb. gain). "Mortality" is the expected percentage of death loss in the pen of cattle. "Corn Price" is the expected corn price based on the relevant futures price adjusted for basis in $ per bushel. "Fed Cattle Price" is the expected selling price of the cattle when finished and sold in November. "Revenue" is the cattle selling price times the expected animal finish weight. "Daily Gain" is the average daily gain over the feeding period (lbs. per head per day). "Days on Feed" is the number of days you plan to keep the animals on feed. "Sell Weight" is the expected weight of the cattle lbs. per head at harvest.

The "Expected Profit per Head" is provided in the box in the center of the page. For this pen, with these attributes, the expected profit is a loss of $4.85 per head.

From here you can access the details of the expected probability distributions of probable outcomes from the calculator. You can access these in two ways: 1) you can review individually the expected distributions for Vet Cost, Feed Conversion, Mortality, Corn price, Fed cattle selling price, Revenue, or Profit by clicking on each phrase highlighted in blue font below the "Expected Profit Per Head" box. 2) Alternatively, you can simply click the PDF icon to the right of the Expected Profit Per Head box and this will bring up a PDF file that contains all of the distributions together for saving and/or printing.

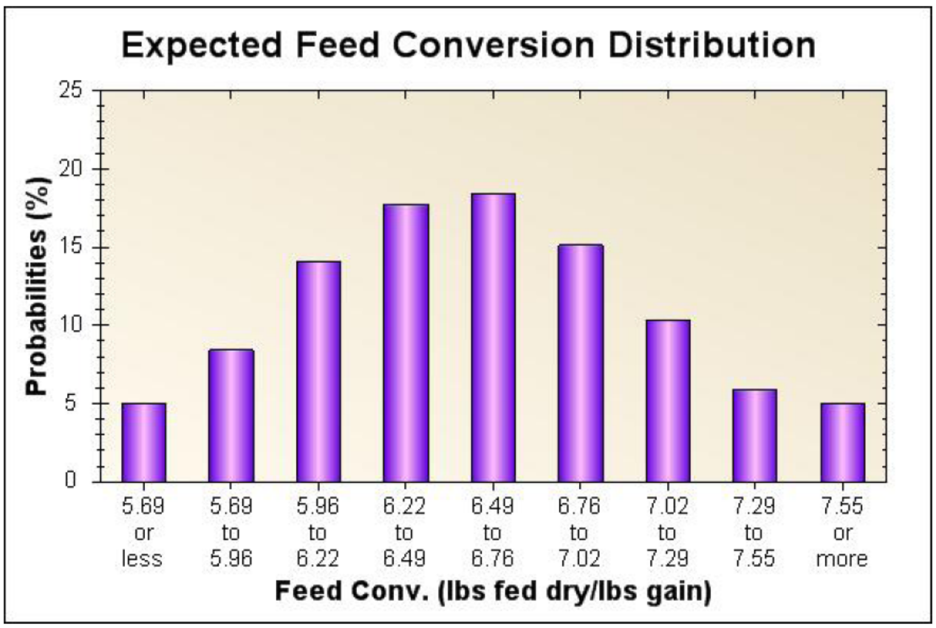
IMPORTANT: The results of your inputs are not stored in the computer or captured anywhere else. So if you wish to do sensitivity analysis with different input values from the first page and compare them, the best way to do this is to save the PDF file on your hard drive by right clicking on it, with a "save target as" and naming and saving it before you enter new inputs on the first page. Alternatively, you may wish to print intermediate results before making any such changes. Exiting out of the web automatically erases all of your inputs and associated output calculations.

STEP III: INTERPRETTING DISTIBUTIONS

The calculator produces distributions of expected outcomes based upon the inputs you supplied, historical cattle feeding performance in the region during that time of year, and recent futures market prices. To better understand these distributions, consider a few examples continuing with the example above.

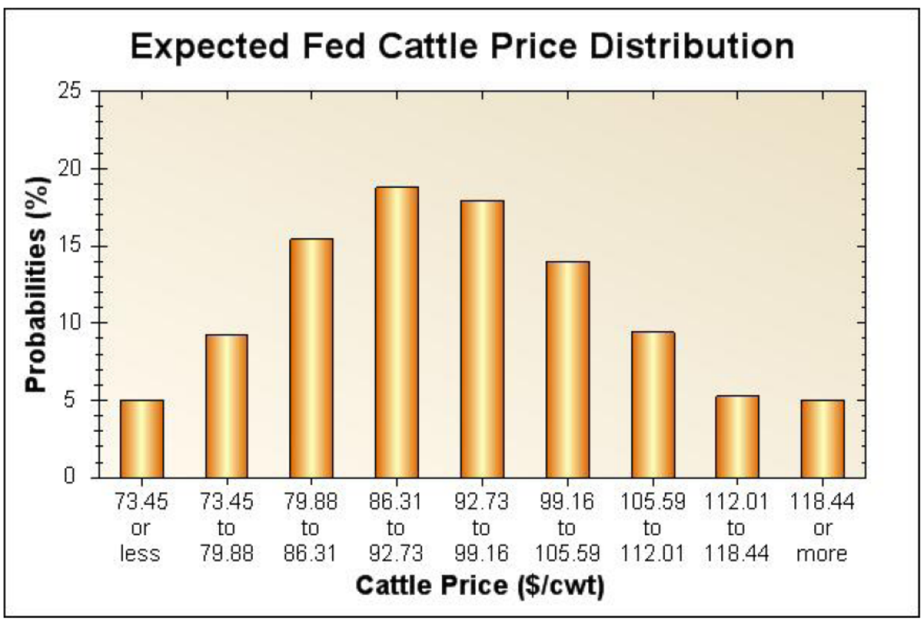
The distribution for dry matter feed conversion is presented below. The table provides the expected probability associated with each range of feed conversion for this pen of heifers. There is a 5% chance that the feed conversion will be less than 5.69 lbs. of feed per pound of gain, an 8.4% chance it will be between 5.69 and 5.96, and so forth. The graph presents a visual plot of these probabilities. The most likely feed conversion range is 6.49 to 6.76, but notice this range only has an 18.4% probability. Overall, this chart provides a glimpse of one dimension of risk associated with feeding this pen of animals.

Feed Conv. (lbs fed dry/lbs gain)	5.69 or less	5.69 to 5.96	5.96 to 6.22	6.22 to 6.49	6.49 to 6.76	6.76 to 7.02	7.02 to 7.29	7.29 to 7.55	7.55 or more
Probabilities (%)	5.0	8.4	14.1	17.8	18.4	15.1	10.3	5.9	5.0



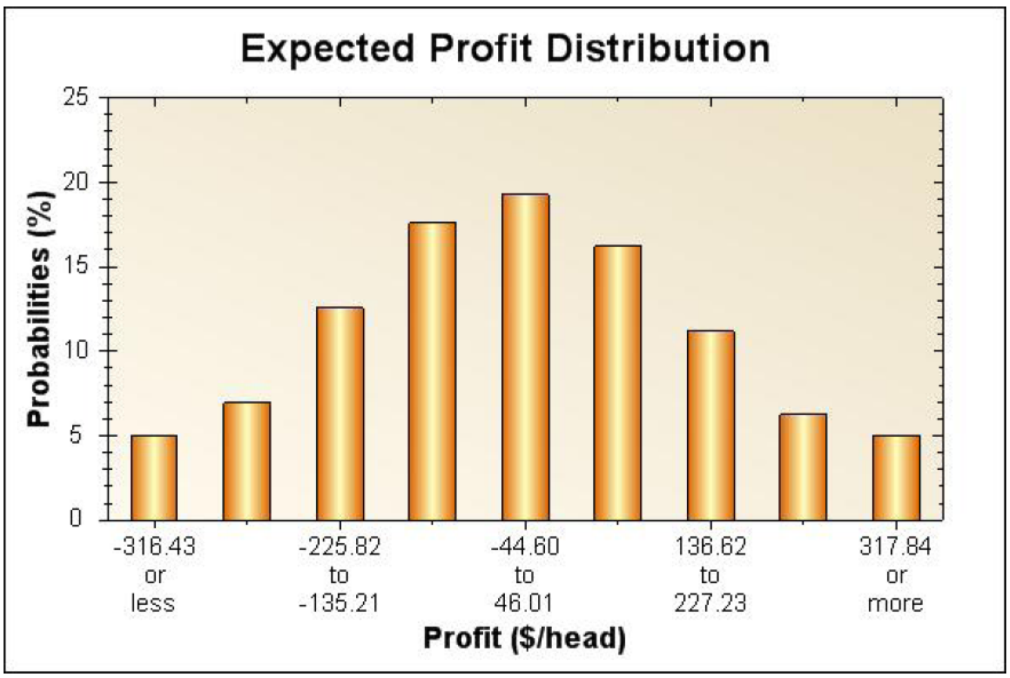
The fed cattle sale price probability distribution reveals one dimension of market price risk present in feeding these heifers. The expected fed cattle price is given by the nearby futures price at the time the cattle are expected to be harvested, adjusted for local basis. The variability in the expected price is derived using live cattle option market premiums (more details are presented in the Calculations section). The expected fed cattle price distribution illustrates that there is a 19% chance price will end up being in the range from \$86.31 to \$92.73/cwt. Taking the largest three probability ranges together, there is a 52% probability (15.4+18.8+17.9) that cash fed cattle price will end up being between \$79.88 and \$99.16/cwt, implying a 48% chance the price will be outside this range. This suggests sizeable fed cattle sell price risk present in feeding cattle based on current market conditions.

Cattle Price ($/cwt)	73.45 or less	73.45 to 79.88	79.88 to 86.31	86.31 to 92.73	92.73 to 99.16	99.16 to 105.59	105.59 to 112.01	112.01 to 118.44	118.44 or more
Probabilities (%)	5.0	9.2	15.4	18.8	17.9	14.0	9.4	5.3	5.0



Each of the individual probability tables and charts are helpful for understanding the nature and source of factors contributing to profit variability. Of utmost interest is the overall return variability. There is a 19.3% change overall net return per head will be between -$44.60 and $46.01 per head. The profit for this pen is centered near zero as the expected average return is a small loss of $4.85 per head. There is a 42.1% chance (5.0+6.9+12.6+17.6) net return will be a loss of $44.60 or more per head. There is also a 38.6% chance (16.2+11.2+6.2+5) net return will exceed $46.01 per head.

Profit ($/head)	-316.43 or less	-316.43 to -225.82	-225.82 to -135.21	-135.21 to -44.60	-44.60 to 46.01	46.01 to 136.62	136.62 to 227.23	227.23 to 317.84	317.84 or more
Probabilities (%)	5.0	6.9	12.6	17.6	19.3	16.2	11.2	6.2	5.0



4. Calculations in the Risk Analyzer

The *Cattle Feeding Return Risk Analyzer©* is comprised of three interlinked modules. The first segment of the calculator uses the information on cattle placement weight, placement date, gender, location, and days on feed to estimate expected feed conversion, veterinary and medication costs, average daily gain, and mortality. The user inputs are fed into a set of equations that have been estimated using a large sample of 10 years of historical cattle feeding performance data in the region. The second module captures live cattle futures and corn futures prices as well as associated options to calculate expected prices and probability distributions. The third and final module combines all of the calculations into a simulation to compute net return and a probability distribution of net return.

Full comprehension of the mathematical models and econometric methods that underlie the risk simulator is not necessary in order to use the simulator. The models were estimated using advanced statistical modeling techniques and provide a sound, scientific basis for the output provided by the risk simulator. In the discussions which follow, we provide statistical details regarding how these models were parameterized. The casual user may not have a strong interest in these mathematical details and the functionality and utility of the simulator for such users will not be compromised by skipping over this material.

Module 1: Cattle Performance Calculations

To estimate the probability density function associated with various measures of cattle feeding performance, models for each measure must be specified to account for deterministic factors (decision variables) involved in cattle feeding. The underlying motivation of these models is to derive conditional probabilistic measures of the distributional properties of feeding performance factors. The first step of the analysis involves identification of relevant conditioning variables that may be associated with risks of cattle production but are of a deterministic nature. These conditioning variables need to be observable at the time that relevant production decisions are to be made (i.e., prior to placement on feed). Conditioning variables such as seasonal effects, pen characteristics, and feedlot-specific fixed effects are included in our empirical models for DMFC, ADG, mortality, and veterinary costs. Seasonal effects, represented by the date the cattle were placed on feed, account for some of the risks associated with weather and other environmental factors. Cattle characteristics, such as gender and average placement weight, also represent important conditioning factors relevant to differences in yield for various pens of cattle. Feedlot-specific characteristics 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:

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

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

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

(4) $VCPH = f_4(gender, location, log(in\text{-}weight), season, DOF)$

where *DMFC* is dry matter feed conversion, *ADG* is average daily gain, *MORT* is mortality rate, and *VCPH* is veterinary and medication cost per head.[2] 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; *season*, a binary variable determined by the placement month; and *DOF*, the number of days the pen is placed on feed.

We hypothesize that these conditioning factors influence mean yields as well as the variability associated with each yield measure. Thus, each regression for *DMFC*, *ADG*, *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 are independently distributed. The model is specified as

(5) $$y_i = \mathbf{x}_i'\beta + \varepsilon_i$$

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 risk associated with each dependent variable (*DMFC, ADG, MORT, and VCPH*). The conditional variance is unique for each observation and is estimated as

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

where α contains parameter estimates for each explanatory variable that weigh each characteristic by its effect on the individual variance term and $\mathbf{z}_i$ contains 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, which is captured by the σ^2 term.[3] Maximum Likelihood estimation is used to estimate Harvey's model for *DMFC, ADG,* and *VCPH* by specifying the following log-likelihood function for the normal distribution

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

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

[2]As we note below, these factors are certainly interrelated and thus joint estimation may offer efficiency gains. We parameterize this correlation structure subsequent to estimation and conduct risk simulations using this parameterized correlation structure. We do not pursue joint estimation in light of the complexity associated with censoring (in the mortality case) and because of our desire to allow the variance terms to depend on the conditioning factors. Joint estimation of a full eight-equation model with mean and variance effects for the four performance measures is a topic of current research.

[3] Note that a separate, additive intercept term cannot be identified in this specification, since σ^2 is a parameter that must be estimated.

Not every pen of cattle in the data set realized mortality losses, 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* must be 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

$$\text{(8)} \quad \log L = \sum_{\forall y_i > 0} -\frac{1}{2}\left[\log 2\pi + \ln\left(\sigma^2\right) + \mathbf{z}_i'\alpha + \frac{\left(y_i - \mathbf{x}_i'\beta\right)^2}{\sigma^2 \cdot \exp\left(\mathbf{z}_i'\alpha\right)}\right] + \sum_{\forall y_i = 0} \ln\left[\Phi\left(\frac{-x'\beta_i}{\sigma^2 \exp\left(\mathbf{z}_i'\alpha\right)}\right)\right]$$

where Φ is the normal CDF. The two parts of the likelihood function correspond to 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 5 and 6, the expected conditional mean and conditional variance of each production 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 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, conditional on factors observable at the time the cattle are placed. This provides both an estimate of the overall expected variability in profits prior to placing cattle on feed and the impact of individual factors such as prices and yield on expected profits and profit variability.

The maximum likelihood estimates of parameters relating to DMFC, ADG, VCPH, and MORT were found assuming multiplicative heteroskedasticity and running four individual regressions. Table 1 summarizes the data used to estimate the models presented here. These data are important because they illustrate the nature of the data used to parameterize the production performance estimates.

Table 1. Variable Descriptions and Summary Statistics

Variable Name	Description	Mean	Standard Deviation	Minimum Value	Maximum Value
DMFC	Dry Matter Feed Conversion (lbs feed / lbs gain)	6.19	0.72	4.39	23.84
ADG	Average Daily Gain (lbs gain / day)	3.36	0.48	0.74	5.78
VCPerHd	Veterinary Cost Per Head ($)	11.83	6.25	0.00	60.00
Mortality	Percentage of pen that die	0.93	1.53	0.00	25.83
InWt	Average weight per head of cattle for the entire pen measured upon entrance (lbs)	737.50	87.22	500.00	900.00
OutWt	Average weight per head of cattle for the entire pen measured upon exit (lbs)	1,177.91	88.10	910.00	1472.00
DOF	Days on Feed (days)	128.83	25.93	68.00	289.00
Winter	Binary variable equal to 1 if entry was between Dec - Feb	0.25	0.44	0.00	1.00
Spring	Binary variable equal to 1 if entry was between Mar - May	0.23	0.42	0.00	1.00
Summer	Binary variable equal to 1 if entry was between Jun - Aug	0.26	0.44	0.00	1.00
Fall	Binary variable equal to 1 if entry was between Sep - Nov	0.25	0.43	0.00	1.00
Steers	Binary variable equal to 1 if entire pen of cattle were Steers	0.51	0.50	0.00	1.00
Heifers	Binary variable equal to 1 if entire pen of cattle were Heifers	0.37	0.48	0.00	1.00
Mixed	Binary variable equal to 1 if pen was mixed	0.12	0.33	0.00	1.00
KS	Binary variable equal to 1 if Kansas feedlot	0.80	0.40	0.00	1.00
NE	Binary variable equal to 1 if Nebraska feedlot	0.20	0.40	0.00	1.00

Total sample size n = 11,397 pens of cattle

Dry Matter Feed Conversion Model

Table 2 shows the 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* appeared to be most closely characterized by a log-normal distribution. This is reflected in a substantial degree of positive skewness in the distribution of residuals from an initial regression of the level 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. More specifically, steer pens have an average feed conversion that is 10% lower than heifer pens.

Parameter estimates for the *KS* binary variable indicate that *DMFC* is 8% lower for the Kansas feedlots relative to the Nebraska feedlots, which is likely the result of different management practices, feedlot structures, or environmental factors. Nebraska pens in our sample typically have lower placement weights and higher fed weights, with an additional 25 days on feed.

The coefficient for *In-Weight* is positive, indicating that higher placement weights decrease feed efficiency (i.e., require higher feed conversion rates). Specifically, a 100 pound increase in average *In-Weight*, corresponds to a 0.12 increase in *DMFC*. The coefficient for squared *In-Weight* is slightly negative, indicating that feed conversion rates increase at a decreasing rate as average entry weight increases. Additionally, two interaction terms control for interactive effects between *DOF* and *In-Weight*.

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 coefficients for both *Winter* and *Spring* are significantly different from *Summer*. Pens placed in winter months are typically on feed as temperatures are warming up into the range of optimal feeding, improving feeding performance relative to temperatures in the hot summer months. *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 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 6 describes the linear equation used to estimate these variances by observation. The heteroskedasticity parameter estimates offer insight into how the conditioning variables affect the variance. The intercept term can be directly interpreted as σ, according to equation 6. Parameter estimates for binary variables can offer information into the effect of the variable on conditional variance.[4] For example, a negative parameter estimate for *Steers* implies a decrease in the conditional variance given a Steer pen. Also *Mixed* pens present the highest variance by gender, followed by *Heifers* and *Steers*. All seasonal variables present significant differences in individual variability when compared to *Summer*.

[4] Evaluating the effect that a positive binary variable, say X_k, has on the conditional variance for a given observation with k parameters can illustrated with the following equation: $\sigma_i^2 |_{X_k=1} - \sigma_i^2 |_{X_k=0} = \exp(\bar{X}_1\alpha_1 + ... + \bar{X}_{k-1}\alpha_{k-1}) \times [\exp(\alpha) - 1]$. From this equation, it can be shown that the difference in conditional variance will be positive when $\alpha > 0$ and negative when $\alpha < 0$.

Table 2. Harvey's Model Results for Log of Dry Matter Feed Conversion

Conditional Mean			
Variables	Parameter Estimate	Standard Error	p-value
Constant	0.9547	0.2026	<.0001
Steers	-0.1045	0.0019	<.0001
Mixed	-0.0393	0.0033	<.0001
KS	-0.0791	0.0022	<.0001
Winter	-0.0047	0.0022	0.0369
Fall	0.0452	0.0024	<.0001
Spring	-0.0152	0.0021	<.0001
Days on Feed	0.0022	0.0014	0.1029
In-Weight	0.0012	0.0006	0.0319
In-Weight_Sq	-3.3E-07	3.9E-07	0.3949
*DOF*In-Weight*	-3.7E-07	3.9E-06	0.9252
*DOF*In-Weight_Sq*	3.2E-10	2.9E-09	0.9098
Conditional Variance			
Variables	Parameter Estimate	Standard Error	p-value
Constant	0.1796	0.2833	0.5262
Steers	-0.1857	0.0224	<.0001
Mixed	0.4675	0.0266	<.0001
KS	0.1160	0.0254	<.0001
Winter	0.0749	0.0261	0.0041
Fall	0.3851	0.0257	<.0001
Spring	-0.2760	0.0284	<.0001
DOF	-0.0329	0.0206	0.1104
In-Weight	-0.0108	0.0085	0.2046
In-Weight_Sq	1.0E-05	5.7E-06	0.0795
*DOF*In-Weight*	1.2E-04	5.8E-05	0.0429
*DOF*In-Weight_Sq*	-8.6E-08	4.0E-08	0.0316

n = 11,397 pens of cattle

Average Daily Gain

Estimation results for the *ADG* equation are contained within Table 3. Most of the parameter estimates for *ADG* are consistent with, though with an inverse sign, to the results contained within the *DMFC* model. This is mostly explained by the high degree of correlation between the two variables. Parameter estimates indicate that *Steer* pens gain weight faster than heifer pens by 0.5 pounds per day. Placement weight is positively correlated with ADG. This result, combined with the higher feed conversion rate associated with heavier weighted pens, implies that pens with heavier placement weights are fed significantly more feed per day than those with lighter placement weights. Pens placed in s*ummer* months have greater gains than at any other time of the year. Each conditioning variable has a significant effect on the expected mean, while most have a significant influence on the variance of ADG.

Table 3. Harvey's Model Results for Average Daily Gain

Conditional Mean

Variables	Parameter Estimate	Standard Error	p-value
Constant	2.5108	0.8537	0.0033
Steers	0.4849	0.0086	<.0001
Mixed	0.1946	0.0126	<.0001
KS	-0.0543	0.0103	<.0001
Winter	-0.1409	0.0097	<.0001
Fall	-0.1972	0.0103	<.0001
Spring	-0.0415	0.0095	<.0001
Days on Feed	0.0132	0.0058	0.0222
In-Weight	0.0079	0.0024	0.0011
In-Weight_Sq	-6.7E-06	1.7E-06	<.0001
*DOF*In-Weight*	-7.5E-05	1.7E-05	<.0001
*DOF*In-Weight_Sq*	5.6E-08	1.3E-08	<.0001

Conditional Variance

Variables	Parameter Estimate	Standard Error	p-value
Constant	0.7091	1.2097	0.5578
Steers	0.1081	0.0291	0.0002
Mixed	0.3799	0.0395	<.0001
KS	-0.1083	0.0351	0.0020
Winter	-0.0322	0.0340	0.3427
Fall	0.2409	0.0339	<.0001
Spring	-0.2181	0.0347	<.0001
DOF	-0.0494	0.0234	0.0344
In-Weight	-0.0104	0.0095	0.2715
In-Weight_Sq	1.3E-05	6.5E-06	0.0512
*DOF*In-Weight*	1.7E-04	6.7E-05	0.0090
*DOF*In-Weight_Sq*	-1.5E-07	4.8E-08	0.0012

n = 11,397 pens of cattle

Mortality Rate Model

Table 4 contains the MLE results for the model described in equation 3, where mortality rate (*MORT*) is the dependent variable. Again, recall that the mortality rate is censored at zero, with many pens realizing no death losses. The coefficients for *Steers* and *Mixed* indicate that both types of pens have higher mortality rates than pens consisting of heifers only, by 0.10 and 0.24 percent, respectively.[5] The coefficient for *KS* indicates that there is not a statistically significant difference in mortality rates between Kansas and Nebraska feedlots. A one percentage point increase in placement weight is associated with a decrease of 0.04 percent in the mortality rate. Placement date does not appear to have a statistically significant effect on expected mortality rate.

[5] To interpret the marginal effects within the Tobit model, MLEs must be multiplied by the proportion of non-censored observations in the sample, which is 53.404% within this data set.

The conditional variance of *MORT* is described by the heteroskedasticity parameters listed in Table 3. All the conditioning variables in the model have a statistically significant effect on the conditional variance of the mortality rate. Pens consisting of steers only have a negative impact on the conditional variance of the 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 the mortality rate is higher for Kansas feedlots, relative to Nebraska feedlots. The conditional variance of mortality rate lowers by 1.7% as placement weight increases by one percentage point. The seasonal variables indicate a lower conditional variance for winter and spring placement and a higher variance of the mortality rate for fall placement, as compared to summer placement.

Table 4. Harvey's Model Results for Mortality Rate

Conditional Mean			
Variables	Parameter Estimate	Standard Error	p-value
Constant	24.0375	1.4098	<.0001
Steers	0.1850	0.0507	0.0003
Mixed	0.4409	0.1010	<.0001
KS	-0.1050	0.0527	0.0465
Log(inwt)	-3.6271	0.2150	<.0001
Winter	0.0662	0.0617	0.2831
Fall	0.0627	0.0696	0.3674
Spring	-0.0792	0.0623	0.2036
Conditional Variance			
Variables	Parameter Estimate	Standard Error	p-value
Constant	561.1711	286.0543	0.0498
Steers	-0.0565	0.0429	0.1876
Mixed	0.8144	0.0616	<.0001
KS	0.2180	0.0493	<.0001
Log(inwt)	-1.7252	0.1567	<.0001
Winter	-0.1931	0.0539	0.0003
Fall	0.2736	0.0533	<.0001
Spring	-0.3155	0.0582	<.0001

n = 11,397 pens of cattle

Veterinary Costs Model

Table 5 shows MLE results for the conditional mean model described by equation 4, where the dependent variable is veterinary costs per head of cattle (*VCPH*). As with the *DMFC* 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 coefficient for *Mixed* indicate that *VCPH* are higher for these pens, as compared to pens of heifers, while steer pens do not appear to be significantly different that heifer pens. The positive relationship between veterinary expenses and DOF is not surprising, given that pens are cared for throughout the feeding period. Alternatively, higher veterinary costs may indicate poorer overall health of the pens, since *VCPH* is a proxy for the general health of a pen of cattle. Mixed pens result in veterinary costs that are 20% higher than heifer pens. Mixed pens average $14.55 in veterinary costs per head, compared to $11.18 and $11.83 for heifer and steer pens, respectively.

Feedlots in Kansas have lower *VCPH*, as compared to Nebraska feedlots. Lower spending on veterinary services per head may be due to differences in management practices, environmental factors, or a higher average of days on feed in Nebraska feedlots. The coefficient for *Inwtlog* indicates that increasing placement weight by one percent leads to a decrease in veterinary costs by 6.0%. This is largely due to the fact that more mature pens have less health problems than younger pens. The coefficients of seasonal binary variables for *Winter* and *Spring* indicate a VCPH lower than summer placements by over 6%. 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 have a statistically significant effect on the conditional variance of *VCPH*. Veterinary services are used as a precautionary measure through pre-treating cattle and also are used in reaction to disease or injuries during the feeding cycle. Pens consisting of steers only 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.

Table 5. Harvey's Model Results for Log of Veterinary Costs Per Head

Conditional Mean

Variables	Parameter Estimate	Standard Error	p-value
Constant	5.9590	0.3815	<.0001
Steers	-0.0050	0.0100	0.6172
Mixed	0.1936	0.0145	<.0001
KS	-0.1506	0.0100	<.0001
Log(inwt)	-0.6015	0.0538	<.0001
Winter	-0.0809	0.0105	<.0001
Fall	0.0019	0.0103	0.8554
Spring	-0.0692	0.0105	<.0001
DOF	0.0039	0.0003	<.0001

Conditional Variance

Variables	Parameter Estimate	Standard Error	p-value
Constant	2.2561	0.6291	0.0003
Steers	-0.3739	0.0142	<.0001
Mixed	0.1600	0.0274	<.0001
KS	0.4289	0.0162	<.0001
Log(inwt)	-0.6686	0.0792	<.0001
Winter	0.3156	0.0152	<.0001
Fall	0.3270	0.0189	<.0001
Spring	0.1436	0.0180	<.0001
DOF	0.0044	0.0004	<.0001

n = 11,397 pens of cattle

Module II: Expected Fed Cattle and Corn Prices

The other two relevant random variables are the expected values and 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 simulations. For fed cattle, the futures contract expiring nearest to, but not before, the expected cattle sale date was used to generate the expected price. A three year historical average basis was used to adjust futures price to local cash price. For corn, contract nearest to, but not expiring before, the middle month of the feeding period is used to generate expected cash corn price. The futures price for corn was adjusted to a local cash price using a three-year historical average basis.

The standard Black-Scholes assumption of log-normality is used to derive probability distributions of corn and fed cattle prices from the implied volatilities taken from options markets. The futures and option market prices used in the calculator are the quotes taken from the previous trading day's settlement prices. The calculator updates new futures and option prices after each trading day and retains those until a new trading day is complete and new settlement prices are captured.

Module III. Profitability of Cattle Feeding

The conditional expected mean and variance of each of the yield factors describes the distributional characteristics of DMFC, ADG, 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 profit risk they face, but also the contributions of individual yield and price volatilities to that risk. Of course, each of these individual sources of risk is potentially related to the others, such that any consideration of overall profit risk must consider the correlation structure inherent in the different risk factors. Although the conditional mean and variance equations were estimated individually, we estimated the correlation structure by considering the correlation among residuals from the estimated equations. In the risk simulations which follow below, we assume that the cross-equation correlation coefficients are constant at the values implied by the estimation sample. Thus, we alter the off-diagonal covariance terms in our simulations as the conditional variance terms change in a manner that holds the correlation coefficient constant.[6]

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

$$(9) \quad \Pi = TR - FDRC - YC - FC - VC - IC$$

where Π 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

$$(10) \quad TR = FP \times CSW \times (1 - MORT) \times (0.96)$$

where *FP* is the price per hundred weight ($/cwt) of fed cattle and *CSW* is the average sale weight of the finished cattle, which is estimated based on the following equation:

$$(11) \quad CSW = CPW + (ADG \times DOF)$$

where *CPW* is the average weight of the feeder cattle at placement and *DOF* is the number of days the pen of cattle is in the feedlot. *TR* is adjusted for death loss using the *MORT* variable and a standard 4% live-weight shrinkage factor is applied to reflect the

[6] The Pearson correlation coefficient is given by the ratio of the covariance to the product of the standard deviations. Thus, as the conditional variance (and thus standard deviations) change, we scale the implied covariance terms to maintain constant correlation. This has the added advantage of maintaining a positive semi-definite conditional covariance matrix. Of course, it would be preferable to parameterize the entire covariance structure and allow all terms to vary with conditioning factors, though this presents a far more complex estimation problem—one that remains a topic of current research.

expected loss in weight during transport from the feedlot to the packing plant. Sell weight is a function of a random performance variable (*ADG*) and therefore is not fixed. This profit function allows the user to specify the expected days on feed, while allowing sell weight to be determined by the average weight upon entry, *ADG*, and the length of time on feed. *FDRC* is defined as

$$(12)\quad FRC = FRP \times CPW$$

where *FRP* is the price per hundred weight of feeder cattle. *YC* is defined as

$$(13)\quad YC = (0.40) \times DOF$$

where \$0.40 is a typical per head day cost for feedlots in Kansas and Nebraska. *FC* is defined as

$$(14)\quad FC = CP \times \frac{1}{56} \times \left\{ \frac{DMFC}{0.88} \times ADG \times DOF \right\}$$

where *CP* is the price per bushel of corn and is divided by 56 to convert this price into a per pound measure. Further, dry feed 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

$$(15)\quad IC = \left\{ \frac{1}{2}\left[YC + FC + VC\right] + FRC \right\} \times DOF \times \frac{IR}{365}$$

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 need to purchase feed throughout the feeding period, while the feeder cattle must be entirely purchased at the beginning of the feeding period.

Within the context of our yield model for cattle feeding, six random variables are relevant as sources of profit risk. The four yield variables, DMFC, ADG, mortality rate, and veterinary costs, are modeled using the conditional mean and heteroskedasticity models discussed above. Unique pen characteristics define an expected mean and variance, which are then parameters within a Normal distribution. Draws are then taken from these distributions to simulate realizations of the yield variables, taking into account the correlation structure. The models of the four 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 expected mean of profits is a function of the variables described in expression (9), while the expected variance of profits is a function of the implied volatility of fed cattle and corn prices, and the variance of DMFC, ADG, MORT, and VCPH.

Simulations of profitability risk are conducted based upon the six-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 four pen-level yield factors and the corn and fed cattle prices. The correlation between the prices for corn and fed cattle is set to -0.1359, based on daily cash prices from 1980 – 2005. 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 with different marginal distributions for each of the six 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 six variable system), it is possible to assess the distributional properties associated with expected profits. This process maintains the correlation structure inherent in the yield factors. For example, the simulation structure maintains the highly correlated relationship between MORT and VCPH, as well as DMFC and ADG.

6. Terms of Use

The *Cattle Feeding Return Risk Analyzer©* was developed in a partnership between North Carolina State University, Kansas State University, U.S. Department of Agriculture Risk Management Agency, and the North American Institute for Beef Economic Research.

The intended use of this calculator is to help cattle feeders quantify expected production and price risk associated with placing feeder cattle on feed given current market conditions and past cattle feeding production risk. The tool is not a forecasting tool, but rather a tool to demonstrate the types of risk present from key sources based on historical records and current market prices.

The calculator relies upon models estimated using historical data for cattle fed in Kansas feed yards and in Nebraska feed yards and is thus parameterized differently for these two locations. Cattle fed in different locations may experience different production and price risk than the calculator presents. Furthermore, the calculator relies upon Chicago Mercantile and Chicago Board of Trade recent futures and options market prices for establishing expected prices and distributions. As a result, the distributions are based upon the market quotes available for futures prices and option premiums and these may or may not be accurate forecasts of actual outcomes. The calculator uses settlement futures and option prices from the previous day's trading, so its accuracy is particularly degraded during times when large market swings occur in the current day's prices. In addition, historical basis data are used for local basis adjustments which may not accurately predict future basis levels.

The tool is intended only to be used as a guide for assessing the recent market-based return and risk present for feeding cattle. No guarantees can be made whether the actual outcomes from any particular group of cattle or any feed yard will fall within the distributions calculated and presented in this tool. This is because a lot of unknown, unexpected, and/or unique circumstances could make realized results different from those estimated in this calculator.

Use of this calculator is at the risk of the user. North Carolina State University, Kansas State University, the North American Institute for Beef Economics Research, and the USDA's Risk Management Agency are not liable for results or outcomes from decisions based upon information obtained from this calculator. Although every effort has been made to ensure a high standard of accuracy, no warranty is expressed or implied and the user assumes all responsibility for actions or decisions based upon the tool's output.