MODELING SURVIVAL OF NORTH DAKOTA COW-CALF OPERATIONS: A MONTE CARLO APPROACH

David L. Watt and Randall D. Little*

Volatile economic fluctuations in the cattle industry, primarily the result of factors beyond the control of individual producers, have a significant impact on profitability. Industry-level beef production, competition from other meat sources, cost of inputs and outputs, weather conditions, governmental policy, and disease represent some of the many sources of risk associated with cattle production. Individual production and marketing decisions in the livestock industry exert little influence in the marketplace.

The survival of individual firms in agriculture is of special interest in the midst of the current economic stress. Results of random surveys of North Dakota farmers and ranchers conducted in January 1985 (Watt et al. 1986) and 1986 generated interest in conditions affecting the longevity of farms and helped motivate this effort to examine ranch survivability.

The Economic Research Service suggests that farms with debt-to-asset ratios of less than 40 percent generally do not have apparent financial stress problems resulting from indebtedness (USDA 1985). Those farms with debt ratios between 40 and 70 percent may have financial stress problems, but those farms with debt ratios exceeding 70 percent may be classified as having extreme financial stress problems.

Cow-calf operations in North Dakota were modeled to estimate survival under alternative debt-to-asset ratios. The average equity position and several alternative equity positions were used to represent the dispersion of the position of individual operators. A modeling of the continuation of current conditions was accomplished by a random draw from a uniform distribution mapped into a magnitude-sorted ordering of historic profitability.

Risk

Knight's definition of risk as a condition of less than perfect knowledge in which an operator knows all possible outcomes of a production process and can place a probability on each event (Knight 1921) is the implicit assumption in this analysis. Risk is often separated into two categories, business and financial risk.

Business risk, which is intrinsic to the firm and separate from the way it is financed, arises from two main sources: (1) price and quantity variation in input and output markets and (2) production risk, including weather and environment (Gabriel and Baker 1980). Financial risk results from

*Watt is assistant professor and Little is research assistant in the Department of Agricultural Economics, North Dakota State University, Fargo.
fluctuation in interest rates and credit availability. It magnifies the
effect of business risk through leveraging. Cow-calf operations are
especially impacted by financial risk because of relatively high investment
requirements per dollar of gross income.

Miller, elsewhere in this publication, lists four categories of risk
that affect beef production: institutional, price or market, weather, and
other natural hazards. Price risk is the result of unpredictable shifts in
the supply and demand of inputs and products. Price risk arising from
fluctuating market prices for weaned calves was modeled in this study. Other
types of risk, although equally important, were not included due to
constraints of the study.

The Monte Carlo Method

The computer model used in this study is based on the Monte Carlo
approach to simulation. A Monte Carlo study is a variance-reducing technique
that involves generating random observations from the distribution under
consideration and then using the average of these observations to estimate the
mean (Hillier and Lieberman 1984).

Monte Carlo modeling has been used for various purposes in traditional
computer languages for some time; however, the length of time required for
computer program development has inhibited its use. The Monte Carlo method
has suffered in popularity because it lacks statistical elegance and
optimization is not possible. Biological processes that take several years to
complete make experimentation irrelevant in a single year decision-making
framework, and data gathering of observations in a particular economic
environment requires too much time to obtain sufficient observations for
statistical analysis.

Monte Carlo modeling is an effective and realistic method for modeling
unpredictable stochastic events that do not fit distributions normally used in
statistical theory. Livestock operations are appropriate for this approach
because actual risks in the livestock industry are complex, interrelated, and
seldom meet the requirements for statistical independence between causal
factors. In the life cycle of the livestock operation, structural changes
required to adjust to developments in the industry take longer than in
industries with shorter production cycles. This paper explores the use of
Monte Carlo modeling to determine the impacts of using experiential
distributions on survival rates of cow-calf operations in North Dakota.

Profitability

The estimates of profitability used in this study were derived in an
earlier study by the authors (Little and Watt 1986). A budget reflecting the
production costs per cow on a typical North Dakota cow-calf operation was
constructed at 1984 price levels. The approach used to construct this budget
was based on the "opportunity cost" (returns foregone in the best alternative
use) of the resource. When using the opportunity cost method, inputs are
valued using current market prices rather than what may have actually been paid for the inputs. Examples include feed, which may be cheaper if produced on the farm than if purchased; operator and family labor, which often remain unpaid; and pasture rent, which on owned land is a fixed cost associated with land ownership. Interest expenses, which are normally included in opportunity cost budgets, were accounted for elsewhere in the model.

Cow-calf production costs were based on an average-sized spring calving operation in North Dakota. The operation annually weaned calves from 90 percent of the cows assumed bred. Technology was assumed constant over the study period. The estimated total cost of production per cow in 1984 was $264.13.

It was assumed that cow-calf operators replaced 16 percent of their cows annually. To allow for this, they retained 18 percent of their calves from which replacements were chosen. Cull cow returns were the product of the replacement rate adjusted for death loss (16 percent minus 1 percent) times the market value of the cow. Cull heifer returns were equal to the replacement rate less the retention rate (18 percent minus 16 percent) times the market value of the heifer. Cull cows and heifers were assumed to be sold at 1,000 and 750 lbs, respectively. A final adjustment to reflect a change in the value of the cow was made to production costs. This was done by subtracting the difference between the previous and current years' value from the total production costs. When cow prices decrease, there is a capital loss which increases production costs; conversely, when cow prices increase, there is a gain in the asset value of the cow which decreases production costs. The adjusted total cost of production per cow was $205.34 in 1984.

The 1984 production costs were adjusted back over time to 1957 using indices of prices paid by farmers. Break-even prices for the cow-calf operation were calculated by dividing the estimated production costs by the hundredweights (cwt) of calf expected to be sold per cow. The cwt of calf sold per cow was the sum of the expected weaning weight of steers times the percent of steers plus the expected weaning weight of heifers times the percent of heifers (4.25 x 45 percent + 4.00 x 27 percent).

The break-even price in a given year was subtracted from an adjusted market price, yielding an estimate of the enterprise's profit per cwt in that year. The adjusted market price used was a combination of prices for both 400-500 lb steers and heifers. At weaning, 63 percent of the calves sold were steers and 37 percent were heifers. The adjusted market price was the sum of the steer price times 63 percent plus the heifer price times 37 percent. Finally, profit per cow was equal to the profit per cwt times the output per cow. The estimates of profit per cow from 1957 to 1984 are presented in Table 1 and illustrated in Figure 1. This method reflects year-to-year variation of cow-calf profitability in North Dakota.

Methodology

Fifty ranches were simulated in each of five initial debt conditions. Average total assets and liabilities for beef ranches in North Dakota were used in the first 50 ranches. The average North Dakota beef ranch has $416,000 of assets, $139,000 of liabilities and a corresponding debt-to-asset
### TABLE 1. ESTIMATED PROFITABILITY PER COW-CALF UNIT ON A COW-CALF OPERATION IN NORTH DAKOTA, 1957-1984

<table>
<thead>
<tr>
<th>Year</th>
<th>Profit ($/cow)</th>
<th>Year</th>
<th>Profit ($/cow)</th>
<th>Year</th>
<th>Profit ($/cow)</th>
<th>Year</th>
<th>Profit ($/cow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>94.78</td>
<td>1965</td>
<td>14.00</td>
<td>1972</td>
<td>112.11</td>
<td>1979</td>
<td>266.34</td>
</tr>
<tr>
<td>1959</td>
<td>22.70</td>
<td>1966</td>
<td>56.48</td>
<td>1973</td>
<td>161.93</td>
<td>1980</td>
<td>47.95</td>
</tr>
<tr>
<td>1962</td>
<td>28.43</td>
<td>1969</td>
<td>57.41</td>
<td>1976</td>
<td>13.60</td>
<td>1983</td>
<td>-29.00</td>
</tr>
<tr>
<td>1963</td>
<td>8.52</td>
<td>1970</td>
<td>44.99</td>
<td>1977</td>
<td>-10.89</td>
<td>1984</td>
<td>-17.66</td>
</tr>
</tbody>
</table>

Figure 1. Estimated Profitability of an Average-Sized Cow-Calf Operation in North Dakota, 1957-1984.
ratio of 33 percent (Watt et al. 1986). The ranches in the remaining debt conditions were of equal size and had initial assets of $400,000. Initial debt levels, including debt free, 40 percent of total assets ($160,000), 55 percent of total assets ($220,000), and 70 percent of total assets ($280,000) were modeled. Financial restructuring options were not considered; therefore, the liabilities were held constant through time.

The profitability for each ranch in each year of operation was drawn at random from the historical expected profitability over the last 28 years. The mechanism used to generate the random draw of profitability was the random number generator in the LOTUS computer package. A uniform distribution of random numbers between 0 and 1 was created. The number generated was used in conjunction with a magnitude-ranked cumulative distribution table with profit per cow estimates from the last 28 years (Figure 2).

Equal probabilities were assigned to each of the 28 profit estimates. Durbin-Watson statistical tests revealed no autocorrelation in the error term. Therefore, profitability in any given year is not modeled to be related to the profitability in the previous year. Using this method, a random number was chosen from the uniform 0, 1 distribution. The associated profitability was interpolated between the 28 magnitude-ranked observations. In this way, the profitability probability was a continuous distribution, although it was not continuously differentiable. The distribution used was actual, not normal, because profitability experienced in the beef operation is not normally distributed. The distribution was drawn from historical market conditions.

The nature of the cattle cycle implies a need to use conditional transitional probability distributions, which would increase the conditional probabilities by a factor equal to the number of conditions specified. The complexity of setting conditions based upon the stage of the cattle cycle requires at least eight states of nature and a level of sophistication beyond what is needed to estimate the incidence of technical insolvency.

The randomly generated profitability was used in the following equation to determine the change in net equity of the ranching operation:

$$E_t = A_{t-1} - L_{t-1} + (P_t \times H_t) \times (1 - C_t) + (I_t \times A_{t-1}) - (I_t \times R_t) \times L_{t-1} - F_t$$

where

- $E_t$ = Equity in year $t$
- $A_{t-1}$ = Assets in year $t-1$
- $L_{t-1}$ = Liabilities in year $t-1$
- $P_t$ = Profit per cow unit in year $t$
- $H_t$ = Number of cows in the herd in year $t$
- $C_t$ = Marginal propensity to consume net profit in year $t$
- $I_t$ = Percentage change in asset value in year $t$
- $R_t$ = Real interest rate in year $t$
- $F_t$ = Family living expenses in year $t$

Net profit was equal to the profit per cow unit times the number of cows in the herd. Percentage change in asset value reflects asset inflation or
Figure 2. Cumulative Distribution of the Estimated Profitability of the Cow-Calf Operation.
deflation. Net profit was multiplied by a marginal propensity to consume to account for some variation in consumption of the family unit relative to net profit. Interest expenses were equal to the real interest rate plus the percentage change in asset value times the liabilities of the operation.

Herd size used was 220 cows; the marginal propensity to consume, 5 percent of net profit; two alternative real interest rates, 3 or 8 percent; and family living expenses, $5,000. Current farm financial problems have been blamed on asset value decline. But in reality, asset value decline affects cash flow only through credit availability. Credit is assumed available up until the point of technical insolvency. Asset value is a very important factor, however it is not addressed in this study. Therefore the percentage change in asset value is zero. Variables in the model are adjustable in any given year.

Results

The number of farms that became technically insolvent by year is presented in Table 2. All of the average North Dakota beef ranches survived when the real interest rate was 3 percent, but 38 percent became insolvent when the interest rate was 8 percent. All ranches with no debt survived with real interest rates of 3 and 8 percent. Only one ranch (2 percent) with a .40 debt/asset ratio became insolvent when the interest rate was 3 percent; however, 90 percent became insolvent with an 8 percent interest rate. Twenty-eight and 96 percent of the ranches with .55 and .70 debt/asset ratios, respectively, became insolvent when the real interest rate was 3 percent. No ranch with these levels of debt survived when the real interest rate was 8 percent.

The cumulative distributions of insolvency over time with real interest rates of 3 and 8 percent are presented in Figures 3 and 4, respectively. Ranches with no debt are not included in either figure and the average North Dakota ranches are not included in Figure 1 because none of these ranches failed. When the interest rate was 3 percent, ranches in the .70 debt/asset category began becoming insolvent in the seventh year. The peak exodus occurred in years 13 through 17 when 44 percent of the ranches became insolvent. The first ranch with a .55 debt/asset level became insolvent in the sixteenth year. Six of the 14 ranches in this debt category became insolvent in year 20.

When the interest rate was 8 percent, the first of the average North Dakota ranches failed in year 15. Over half of the failures in this category occurred in years 23, 24, and 25. Ranches with .70 debt/asset ratios began failing in the fourth year and all had become insolvent by the tenth year of the study. The first ranch with a .55 debt/asset ratio became insolvent in year 7. Sixty-eight percent of these ranches failed between years 9 and 12, and the last ranch became insolvent in year 19. Farms with a .40 debt/asset ratio began failing in year 13, with years 19, 22, and 23 having the highest number of failures.

Net equity increased on only 8 percent of the 50 average North Dakota ranches when the interest rate was 3 percent (Table 2). The average increase on these ranches was $56,035. The remaining ranches lost an average of
| Year | Interest Rate: 3% | | | | Interest Rate: 8% | | | |
|------|------------------|---|---|---|------------------|---|---|---|---|
|      | 0 | 40% | 55% | 70% | ND | Ave. | 0 | 40% | 55% | 70% | ND | Ave. |
| 1    | 0 |     |     |     |     |     | 0 |     |     |     |     |     |
| 2    | 2 | 1   | 1   | 1   | 2   | 1   | 2 |     |     |     |     |     |
| 3    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 4    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 5    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 6    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 7    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 8    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 9    | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 10   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 11   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 12   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 13   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 14   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 15   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 16   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 17   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 18   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 19   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 20   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 21   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 22   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 23   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 24   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| 25   | 1 | 1   | 1   | 1   | 1   | 1   | 1 |     |     |     |     |     |
| Total| 0 | 1   | 14  | 47  | 0   | 0   | 0 | 45  | 50  | 50  | 19 |     |
| Percentage| 0 | 2   | 28  | 94  | 0   | 0   | 0 | 90  | 100 | 100 | 38 |     |
| Net Equity Change: | | | | | | | | | | | | |
| Increase | 33 | 0   | 1   | 0   | 4   | 30  | 0   | 0   | 0   | 0 | 0   | 0 |
| Decrease | 17 | 50  | 49  | 50  | 46  | 20  | 50  | 50  | 50  | 50 | 50  | 50 |
Figure 3. Cumulative Percent of Insolvencies at a Three Percent Real Interest Rate for various debt categories.

Figure 4. Cumulative Percent of Insolvencies at an Eight Percent Real Interest Rate for various debt categories.
$96,793 in net equity over the study period. Net equity decreased an average of $84,567 per ranch on all ranches in this category. Sixty-six percent of the ranches with no debt experienced increases in net equity that averaged $49,144 over the 25-year study period. The remaining ranches had losses in net equity that averaged $41,738. Net equity increased an average of $18,244 per ranch on all ranches with no debt.

All 50 ranches in the .40 and .70 debt/asset categories and 98 percent of the ranches in the .55 debt/asset category experienced losses in net equity when the real interest rate was 3 percent. The surviving ranches with a .40 debt/asset ratio averaged $108,370 in losses in net equity over the 25-year period. One ranch in the .55 debt/asset category had an increase in net equity of $1,940. The remaining ranches had losses in net equity that averaged $101,086. The average loss in net equity on the 36 surviving ranches with a .55 debt/asset ratio was $98,244. Only 6 percent of the ranches in the .70 debt/asset category remained solvent when the interest rate was 3 percent. These ranches averaged $83,470 in net equity losses over the 25-year period.

All ranches carrying debt lost net equity when the real interest rate was 8 percent. The 62 percent of average North Dakota ranches that survived had an average decrease in net equity of $217,901. Sixty percent of the ranches with no debt had increases in net equity averaging $58,170 over the 25-year period. The remaining ranches had losses in net equity that averaged $39,344. Net equity increased an average of $19,164 per ranch on all ranches with no debt. Only 10 percent of the ranches in the .40 debt/asset category survived when the interest rate was 8 percent. These ranches had losses in net equity that averaged $229,006. No ranches with debt/asset ratios of .55 and .70 survived.

Conclusions

The Monte Carlo model performed as expected under varying macroeconomic conditions and across debt/asset categories. It is of interest that North Dakota beef farms at average debt/asset levels can survive well at a 3 percent real interest rate but not at an 8 percent real interest rate. In fact, it appears that a 40 percent debt/asset ratio does not insure survival for beef operations even at the 3 percent real interest rate.

This paper had the goal of demonstrating the use of Monte Carlo modeling using a microcomputer and spreadsheet software. This has been successful, but as in any simulation modeling activity, an increase in complexity would result in a more realistic model.

The model developed in this study provides the skeleton upon which more complicated models can be built as additional information on risk with respect to production is incorporated. Relationships between outcomes can also be reflected in the model structure.
References


