Investment, production, and marketing strategies for an Iowa cattle feeder in a risky environment

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Investment, Production, and Marketing Strategies for an Iowa Cattle Feeder in a Risky Environment

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Investment, Production, and Marketing Strategies for an Iowa Cattle Feeder in a Risky Environment*

by Donald Johnson and Michael Boehlje**

It is widely accepted that agriculture is one of the riskier industries in the United States; the wide fluctuations experienced in grain and livestock prices are well known (Nelson et al., 32, pp. 131-132). Cattle feeding in recent years has been notoriously volatile in profitability, resulting primarily from fluctuations in feed costs and feeder cattle and fed cattle prices (Futrell and Burns, 12).

Risk management is important for a successful farm operation (Nelson et al., 32, pp. 169-184). One possible way to manage risk is through the choice of firm size and leverage (debt in relationship to total assets) configuration. As farm size is increased, the need for nonequity funds to finance land and machinery purchases as well as operating expenses becomes larger. Greater use of credit results in larger fixed repayment commitments, and a drop in income creates the possibility that obligations may not be met (Nelson et al., 32, p. 97). In that case, past savings of the firm would need to be used, and the accumulated wealth of the firm could be seriously or totally impaired. Consequently, a cautious or risk-averse farmer would be expected to rely more on internally generated funds rather than on credit to finance asset expansion and production expenses. This more conservative use of borrowed funds implies that the firm employs fewer assets than if it were more highly leveraged.

Diversification of activities is a well-known means of coping with risk (Samuelson, 37, p. 1). This strategy allows a below-average outcome in one enterprise to be partly or completely offset by an above-average outcome in another. Flexibility in production (e.g., through the planting of different crops or through the staggering of livestock placements) is a widely accepted means of diversification.

Marketing strategies can be used to cope with risk. Just as a farmer diversifies production to smooth the impact of price fluctuations, an individual also can achieve an averaging effect by diversifying marketing activities. This can mean the sale of products at several times during the year as well as proportioning sales between cash and hedged sales. Recent research has indicated the potential to reduce risk through various marketing strategies (Leuthold, 22, pp. 22-24).

Risk and risk management options must be considered in farm firm analyses. The most common type of risk analysis applied to agriculture has been that of selecting an enterprise combination for a fixed resource base (Freund, 11; Hazell, 14; and Thomas et al., 45). Less frequently, longer-range decision models in which the resource base is variable have been constructed (Chen, 5).1

OBJECTIVE

The overall objective of this study is to explore the management strategies that might be used by a midwestern cattle feeder in an environment of price and production risk. The setting chosen for the study is northwestern Iowa—an area of the state in which cattle feeding is more common. The analysis utilizes a numerical model designed to allow flexibility in coping with risk in three main ways:

1. One is to allow variation in farm size. This is done by providing opportunities to acquire land, machinery, and feedlot capacity with both debt and equity and by allowing initial firm size to vary.

2. The second method is through diversifying the production plan. The farmer is allowed to produce corn and soybeans as well as to use several different cattle feeding programs.

3. Finally, the firm can use different marketing activities to sell output. If desired, a farmer could market each commodity several different ways, thereby achieving additional diversification.

The analysis integrates decisions regarding investment, financing, production, and marketing into a common framework. All decisions are made considering the operator's attitude toward risk. Because of the inclusion of time and risk, the analysis is multiperiod and stochastic. A key hypothesis to be tested is whether or not a farmer can assume greater risk in other areas (e.g., production) by using various marketing strategies to reduce risk.

THEORETICAL CONSTRUCTS

Risk can be ignored in economic models only with a loss of realism. The desirability of incorporating risk into the decision-making process is generally accepted, and maximization of expected utility has become widely used in studies of risk (Walker and Nelson, 51). Consequently, that approach is followed in this study.

1A comprehensive review and bibliography of studies analyzing risk in agriculture has been prepared by Walker and Nelson (51).
Expected Utility

The expected utility approach involves two key tenets. One is that risk is represented by some random variables (e.g., prices) for which probabilities can be specified. Secondly, a utility function that provides preference rankings for nonstochastic events can be defined for a decision maker. By combining probability functions with a utility function, a means of evaluating random events is obtained. If random outcomes are discrete, then expected utility for some prospect \( Y \), which offers outcomes \( x_1, \ldots, x_n \) with probabilities \( p_1, \ldots, p_n \), respectively, can be calculated as

\[
E[U(Y)] = p_1 U(x_1) + p_2 U(x_2) + \ldots + p_n U(x_n). \tag{1}
\]

If several prospects are available (e.g., \( Y_1, \ldots, Y_n \)), then the one with the highest expected utility is the preferred option. If working with continuous functions, expected utility is the integral:

\[
E[U(Y)] = \int_{a}^{b} U(x) \, dx, \quad a < x < b, \tag{2}
\]

where \( U(x) \) is the utility function, and \( f(x) \) is the probability density function.

Most studies of the firm under uncertainty assume that the manager displays risk-averse behavior. Risk aversion means that a decision maker prefers a known situation to a risky situation if both have the same expected outcome. Consequently, utility is concave in income or wealth, and the second derivative of utility with respect to income or wealth is negative.

Another common assumption is that a decision maker shows decreasing absolute risk aversion; this means that he (she) becomes more willing to accept a given risk the higher is his (her) income or wealth. Mathematically, absolute risk aversion is defined as:

\[
R_A(Y) = -\frac{U''(Y)}{U'(Y)} \tag{3}
\]

where \( U'(Y) \) and \( U''(Y) \) denote the first and second derivatives of utility with respect to income or wealth, respectively. Decreasing absolute risk aversion implies that the third derivative of utility with respect to income is positive (Pratt, 35, p. 122). Samuelson has suggested that the previously discussed characteristics are sufficient to develop a fairly extensive theory of a firm in a world of uncertainty (38, p. 537).

Studies by Officer and Halter (33) and Lin et al. (23) have attempted to apply an expected utility analysis to a farm setting. Both studies used a game-theory technique (the Ramsey model) to assign utility values to alternative farm plans whose mean income and variance of income lie on the same indifference curve (Dillon, 7). The rate of substitution or trade-off between the mean and variance of income as:

\[
\frac{\partial \mu_I}{\partial \sigma_I^2} = -\frac{\partial U}{\partial \sigma_I^2} \frac{\partial \mu_I}{\partial U} = -\frac{c}{b + 2\mu_I} \tag{5}
\]

where \( \mu_I \) is the mean of 1 and \( \sigma_I^2 \) is the variance of 1 about \( \mu_I \). The quadratic utility function just given implies a utility surface in the three dimensions \( U, \mu_I, \) and \( \sigma_I^2 \). Holding utility constant, the function can be represented by a series of iso-utility curves in mean-variance space. Setting utility equal to a constant level, say \( U^* \), and rearranging terms, the curve of all mean-variance combinations that yield the same level of utility is:

\[
\sigma_I^2 = \frac{U^*}{c} + \frac{a}{b} - \frac{b}{c} \mu_I - \mu_I^2. \tag{6}
\]

Such curves are known as E, V indifference curves because the decision maker would be indifferent between the alternative farm plans whose mean income and variance of income lie on the same indifference curve (Dillon, 7).

The direct solution of an expected utility problem is difficult. Consequently, there has been considerable research on transforming expected utility problems into a more manageable form for empirical analysis; generally these transformations result in a mean-variance analysis. One transformation procedure that has been widely used in agricultural studies is to assume that a farmer possesses a quadratic utility function (Markowitz, 25; Markowitz, 26; Scott and Kliebenstein, 40; and Van Horne, 50). If the income or wealth earned from a farm plan is uncertain, the quadratic utility function may be written as:

\[
U = a + b \cdot E(I) + c \cdot E(I^2) \tag{4}
\]

where \( U \) is utility, \( E(I) \) is expected wealth, and \( a, b, \) and \( c \) are parameters. Since \( E(I) = \mu_I \) and \( E(I^2) = \mu_I^2 + \sigma_I^2 \), this quadratic utility function may be rewritten in terms of the mean and variance of income as:

\[
U = a + b \mu_I + c \mu_I^2 + c \sigma_I^2 \tag{5}
\]

where \( \mu_I \) is the mean of I and \( \sigma_I^2 \) is the variance of I about \( \mu_I \). The quadratic utility function just given implies a utility surface in the three dimensions \( U, \mu_I, \) and \( \sigma_I^2 \). Holding utility constant, the function can be represented by a series of iso-utility curves in mean-variance space. Setting utility equal to a constant level, say \( U^* \), and rearranging terms, the curve of all mean-variance combinations that yield the same level of utility is:

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Such curves are known as E, V indifference curves because the decision maker would be indifferent between the alternative farm plans whose mean income and variance of income lie on the same indifference curve (Dillon, 7).

The rate of substitution or trade-off between the mean and variance at a constant level of utility (assuming a quadratic utility function) is given by:

\[
\frac{\partial \mu_I}{\partial \sigma_I^2} = -\frac{\partial U}{\partial \sigma_I^2} \frac{\partial \mu_I}{\partial U} = -\frac{c}{b + 2\mu_I} \tag{5}
\]

where \( \mu_I \) is the mean of I and \( \sigma_I^2 \) is the variance of I about \( \mu_I \). The quadratic utility function just given implies a utility surface in the three dimensions \( U, \mu_I, \) and \( \sigma_I^2 \). Holding utility constant, the function can be represented by a series of iso-utility curves in mean-variance space. Setting utility equal to a constant level, say \( U^* \), and rearranging terms, the curve of all mean-variance combinations that yield the same level of utility is:

\[
\sigma_I^2 = \frac{U^*}{c} + \frac{a}{b} - \frac{b}{c} \mu_I - \mu_I^2. \tag{6}
\]
The term \((b + 2c\mu)\) is the marginal utility of income \((\partial U / \partial \mu)\) and must be positive for the rational producer. Therefore, the rate of substitution between the mean and variance will be positive, zero, or negative within the relevant range as \(c\) is negative, zero, or positive, respectively. The rate of substitution will be positive for a risk averter \((c < 0)\) because a risk averter requires an increase in mean income to compensate for an increase in variance if the level of utility is to remain constant.

Equations [5], [6], and [7] describe a family of indifference curves given the decision maker’s values for the parameters \(a\), \(b\), and \(c\). Figure 1 shows a family of indifference curves for a risk averter who has a quadratic utility function. The intercept of an indifference curve with the \(\mu\) axis \((\sigma_1^2 = 0)\) is the certainty equivalent of all mean-variance combinations on that indifference curve.

Although empirical studies have shown that quadratic utility functions frequently represent farmers’ behavior, use of such functions has been criticized on theoretical grounds. But Tobin (46) has shown that when risky outcomes are normally distributed, expected utility problems can be transformed into mean-variance analyses. Furthermore, no conditions need be imposed on the utility function.

Johnson and Boehlje (19) derived a set of general conditions under which mean-variance procedures can be substituted for expected utility analyses. Using those conditions,\(^3\) it was shown that a Taylor series expansion of the expected utility function involved only the mean and variance as parameters. Special applications include normal, triangular, and double exponential distribution functions for random outcomes with negative exponential and logarithmic utility functions.

Using a mean-variance analysis to approximate expected utility leads to quadratic programming as a computational technique (Freund, 11; McFarquhar, 27; Stovall, 43; Takayama and Batterham, 44). Quadratic programming assumes that the farmer is a risk averter, or that his indifference curves are convex as shown in Figure 1. The rational farmer thus restricts his choice to those farm plans that have a minimum variance given an expected level of income. Such plans are called efficient \(E, V\) pairs and define an efficient \(E, V\) frontier over the set of all feasible farm plans (segment OM in Figure 2). The point of tangency between the efficient \(E, V\) frontier and an indifference curve defines the farm plan that will maximize the farmer’s utility. The point \(F\) in Figure 2 is the point of utility maximization; associated with point \(F\) is the optimal farm plan for the farmer with a utility function depicted by the indifference curve in Figure 2.

\(^3\) Required conditions are:
1. derivatives of utility functions alternate in sign, beginning with a positive first derivative,
2. probability distributions are symmetric, and
3. probability distributions for the outcomes are mean-preserving transformations of each other.

When these conditions hold, using the first two terms of the Taylor’s expansion provides the same ranking among strategies as does the entire expansion. Solution of a quadratic program provides a frontier that contains the optimal solution.
Model Structure

In most farm management studies, it is common to assume some fixed resource base and then allow the model to activate investment or disinvestment activities to alter the asset structure. One of the hypotheses of this study, however, is that risk preferences are reflected in farm size, i.e., a very risk-averse individual is more likely to farm fewer acres and feed a smaller number of cattle than a farmer who is more indifferent to risk. Thus, the model was structured so that initial firm size could be variable; this involved including activities to determine the amount of land and machinery owned at the start of the planning horizon. The model could then determine optimal firm size by choosing activity levels for these items somewhere between zero (i.e., do not operate a farm) and some predetermined maximum. Investment activities in land, machinery, and feedlot capacity were provided if further expansion in farm size was desired. The combination of a variable firm size at the start of the planning horizon and investment activities during the horizon provided the model considerable latitude in determining the optimal scale of operation for different levels of risk aversion.

Most assets provide a flow of benefits that extend over several years; a model that incorporates asset changes must adequately account for this feature. In this study, a multiperiod model was used to reflect the flow of asset services over time.

Objective Function

Maximization of present values has been used in objective functions of numerous multiperiod linear programming studies (Irwin, 18, pp. 84-91). This procedure involves discounting all future net cash flows to their present value and then maximizing this sum. Such an approach leads to several problems:

1. The choice of an appropriate discount rate may be quite arbitrary.
2. Depending upon the length of the time horizon, some investment activities will be penalized relative to others. For example, in a 10-year model, purchase of land, which has essentially an infinite life, may be at a disadvantage to purchase of machinery with a life span of perhaps 8 years. Although a longer horizon may eliminate this problem, computing costs may become quite large.
3. A third problem is that emphasis on the value of production services neglects the fact that asset worth may be changing. Plaxico and Kletke (34) argue that unrealized capital gains have current value because they increase the firm's borrowing capacity. This allows the firm to purchase additional assets, thereby increasing wealth. When unrealized capital gains are large (as has occurred in recent years with land), recognition of the value of such gains may provide more realistic results.

As an alternative, Lutz and Lutz (24, p. 17) have suggested that an entrepreneur will want to maximize the rate of return on his owned capital because this will provide the owner with the maximum capital sum at the end of the period. A method of implementing this objective is to maximize ending wealth or net worth. Boussard (3, pp. 468-471) also contends that a net worth objective function is superior because it requires a shorter planning horizon than does the present-value rule.

In this study, the firm's objective is to maximize expected utility of ending net worth. One added feature is that assets are valued at current prices. The reason for doing this is to recognize that capital gains have value to the firm.

Covariance Matrix

One of the assumptions of this study is that a decision maker formulates personal probabilities concerning stochastic events (Markowitz, 26, p. 257). These personal probabilities are used by the individual to maximize expected utility. Use of these concepts implies that a farmer, at least subconsciously, forms an opinion about the distribution functions of random variables; e.g., corn prices or profit margins on feeding steers. These probability functions, along with his utility function, can be used to determine a preferred strategy.

A farmer was assumed to use the following concepts in formulating personal probabilities. Statistical tools were then used to translate these concepts into a covariance matrix. Specifically, the following assumptions were made:

1. Prices of capital items increased steadily throughout the past 10 years owing to inflation. For these items, a farmer would think in terms of a certain percentage increase; e.g., machinery prices are expected to increase 10 percent per year. Consequently, an autoregressive model would be appropriate. Prices of grain and livestock have experienced both upward and downward fluctuations over time. For such items, a farmer would think of some average value over time with adjustment for inflation. A linear time trend is an appropriate tool in this situation.
2. A farmer does not recognize covariances among variables of different time periods. This implies that residuals from the regression equations are treated as if they were serially uncorrelated, and that the variance matrix is block diagonal.
3. A farmer does not consider that probability functions change during the planning horizon. Therefore, the diagonal covariance matrices are the same for each year.

Although different reasoning was used, other studies have derived covariance matrices in much the same way (Batterham, 1, pp. 143-149; Chen, 5, pp. 59-61).

EMPIRICAL MODEL

Model Structure

At the beginning of the first operating year, a production and investment plan for the planning horizon is

The four axioms of behavior, which parallel those given for expected utility, and the proof of the existence of personal probabilities are stated in Markowitz (26, pp. 257-273). A more detailed exposition is given by Savage (39, pp. 27-68).
Table 1. The Quadratic Programming Matrix Used in the Numerical Analysis.

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formulated. A 4-year horizon is used because asset activities have effects that extend beyond 1 year. Four years are used because linear programming solutions suggested that this is sufficient to stabilize the first-period results, which are the only results that must be implemented before new information becomes available (Modigliani and Cohen, 31).

Table 1 shows the design of the matrix organized by key sectors. Activities are included for only the first year in Table 1 because subsequent years differ only in the omission of initial firm size and asset-disposal activities. Constraints for 2 years are shown to provide an indication of the interaction among years. The subsequent discussion is organized around the constraint sectors.

**Objective function**

As noted earlier, the objective function of the firm is to maximize expected utility of terminal net worth. Terminal net worth consists of the amount of cash on hand at the end of the planning period plus the ending value of all assets less liabilities.5 Following Reid et al. (36, pp. 29-31), a discounted capital gains tax liability is not included because the firm is expected to have a life span longer than the planning horizon.

**Structural equations**

The cash-constraint sector (Table 1) accounts for cash flow requirements within the year and the payment of taxes at the end of the year. Specifically, this sector contains three equations: one to handle cash payments in the first 6 months of the year, the second to accommodate cash flows in the last 6 months, and the third equation properly accounts for tax payments and consumption. Transfer activities allow unused cash balances in one period to be available in the following period. The cash rows have a balance of $40,000 (the initial endowment of cash) at the beginning of the first year and are augmented by sales of crops and livestock in later periods. Short-term borrowing activities also are available to increase cash availability in different periods.

A debt-limit equation is entered for each year to calculate maximum borrowing capacity, with the limits determined by the value of fixed assets owned at the start of the year. Initial firm assets affect debt limits in all 4 years; but new investments add to borrowing ability only in the years after they are purchased. Short-term borrowings affect the debt-limit equations for the year in which the loan is made while long-term borrowings affect debt equations in all years in which principal is outstanding.
A labor sector is entered for each year to ensure that sufficient manpower is available for growing crops and feeding livestock. Initial labor resources consist of the owner's available time, although labor services can be hired.

One of the model's features is that the asset structure at the start of the period is variable; i.e., initial farm size (acres and machinery capital) can vary within a specified range. The maximum firm-size sector of the model specifies upper limits for machinery and land; initial size activities determine the amount of those limits that will actually be included in the solutions. Equations and activities used to determine initial size are entered for only the first year.

Asset service sectors also are entered for each year, with resource availability transferred from initial size and investment activities. As shown in Table 1, these activities provide services (cropland, machinery services, and feedlot space) in all future years. Asset services are used to grow crops and feed livestock.

Crop and feed inventories sectors consist of the transfer equations needed to make either feed available for cattle or grain available for sale. In the first year, crop inventories from previous production are present, and they can be increased through feed-purchasing activities. Crops grown in a given year increase inventories for the next year, but no provisions are made for transferring inventories from year to year.

Borrowing sectors provide the equations necessary to finance asset purchases with long-term and intermediate-term borrowing. Separate equations for land, machinery, and feedlot investments are provided for each year.

**Covariance Matrix**

A covariance matrix is entered for each period of the model. Because farmers are assumed to ignore variance relationships among time periods, the matrix is block diagonal. Table 1 indicates that variances and covariances have been calculated for all activities affecting net worth except financial activities. Interest rate expectations are assumed to be held with perfect certainty.

To calculate expected net-worth values (which are used in the objective function) and the covariance matrix, time series of asset and product prices were first constructed for the years 1966 through 1977. Regressions were then run to calculate predicted values for the years 1966 through 1981 for each price series. The predicted values for 1978 through 1981 were used in calculating expected net-worth coefficients, and the differences between predicted values and actual values for the years 1966 through 1978 were used to calculate the covariance matrix. This matrix is used as the diagonal covariance matrix for each year in the model.

**Initial Resources**

Iowa Farm Business Association records for individual farms (Iowa Farm Business Association, 17), Iowa Cooperative Extension Service publications (McGrann and Stoneberg, 28; Stoneberg and Edwards, 42), and Census of Agriculture data (U.S. Department of Commerce, Bureau of the Census, 49) were reviewed to gain insight into the resource structure of Iowa farms, particularly those in northwestern Iowa. Production coefficients and an asset base for a representative farm were derived on the basis of these data.

**Land**

Flexibility is provided through initial sizing activities so that farm size can vary, depending upon the operator's attitude towards risk. Costs of holding owned land are stated on a per-acre basis, and the program determines optimal acreage within the range of 0 to 320 crop acres. Rented land can vary from 0 to 320 crop acres (341.3 actual farm acres). Land is assumed to be of high quality, and its value is adjusted each year to reflect price increases (Appendix Table 1).

Fixed costs of holding land include depreciation, insurance and repairs, taxes, and repayment of mortgage debt. Depreciation is held constant throughout the horizon, but insurance and repairs are increased 7.5 percent per year. Property taxes are computed at the rate of $0.80 per $100 of land value, using the land value for the previous year as the tax base.

**Machinery**

First, a machinery complement needed for the representative farm was specified. The physical machinery items were then combined into a common resource by valuing each machine at 1978 prices. Thus, the machinery resource, although stated in dollar figures, is linked to a physical quantity of machinery. The total value of the complement in 1978 prices was $116,250, which reflects the amount of the machinery resource needed to farm 450 acres, regardless of crop.

Machinery was revalued each year to reflect depreciation and price increases (Appendix Table 2). The current-value figures are used to determine borrowing capacity and net worth in the model. For physical capacity purposes, machinery is assumed to have a 10-year life, after which it is salvaged. For tax purposes, depreciation is computed on a 10-year double-declining-balance basis with a 20-percent salvage value.

As with land, the existing machinery activity is structured so that initial capital could range from none to $116,250; assumed risk preferences again determine the initial level.

**Other resources**

The other resources include $40,000 in cash and crop inventories. The farmer is assumed to have planted 150 acres of corn on the owned land in the year 6. Of the owned land, 160 acres is assumed to have been purchased in 1967 with a 20-year loan at 6 percent interest, and the remaining 160 acres is assumed to be owned without debt. In the model, the completely owned and the financed land are combined into one activity, and all coefficients are then stated on a per-acre basis. By using a per-acre basis, some very large coefficients that might cause computation problems are eliminated.
before analysis, which provides a maximum of 18,135 bushels of corn (120.9 bushels per acre) or 2,910 tons of silage (19.4 tons per acre) to start a cattlefeeding enterprise the first year. Again these crop inventories are reduced, proportionally, if risk aversion suggests a smaller initial firm size.

**Labor**

The operator's labor is available to the firm at no direct charge. Hours provided by the operator per month are shown in Table 2. Labor was entered on a quarterly basis except for May, the month in which seedbed preparation and planting are accomplished, when a separate labor restriction was entered.

**Balance sheet**

The beginning balance sheet for the maximum size firm is given in Table 3. Initially, the firm has a very high net worth (roughly 92 percent of assets) and is in a financial position to undertake a large expansion, should the operator be so inclined. Initial net worth of smaller firms would be $40,000 from cash, $0.82 for each bushel of corn in inventory, $1,966 for each acre of land held, and $0.25 for each dollar of machinery capital held.

**Investment Activities**

Investments allow the firm to alter its asset structure. Possible investments include purchasing land, machinery, building a feedlot, and off-farm investment.

*Table 2. Labor Availability Assumed in the Numerical Analysis. a/*

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Month</th>
<th>Hours Available</th>
<th>Total for Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>February</td>
<td>192</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>March</td>
<td>208</td>
<td></td>
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<tr>
<td></td>
<td>April</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>May</td>
<td>270</td>
<td>736</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>216</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>August</td>
<td>208</td>
<td>738</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>November</td>
<td>250</td>
<td>666</td>
</tr>
<tr>
<td></td>
<td>December</td>
<td>208</td>
<td></td>
</tr>
<tr>
<td></td>
<td>January</td>
<td>208</td>
<td></td>
</tr>
</tbody>
</table>

a/(Kay, 20, p. 285).

*Table 3. Balance Sheet of the Representative Firm Used in the Numerical Analysis.*

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities and Net Worth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash $40,000</td>
<td>Income Tax Liability $14,780</td>
</tr>
<tr>
<td>Corn (18,135 bu. at $1.65)</td>
<td>Mortgage on Machinery 11,316</td>
</tr>
<tr>
<td>Machinery 39,928</td>
<td>Mortgage on Land 11,738</td>
</tr>
<tr>
<td>Land (320 A. at $2065)</td>
<td>Total Liabilities 57,834</td>
</tr>
<tr>
<td></td>
<td>Owner's Net Worth $712,454</td>
</tr>
<tr>
<td><strong>Total Assets</strong> $770,288</td>
<td><strong>Total Liabilities and Net Worth $770,288</strong></td>
</tr>
</tbody>
</table>

**Land**

Land can be purchased at the start of each year with a 20-percent down payment and the balance financed by a 20-year land mortgage. Charges for taxes, insurance, repairs, and depreciation are assumed to be the same as for the land owned initially. A summary of the data used in developing coefficients for land purchases is provided in Appendix Table 1.

**Machinery**

Machinery can be purchased at the start of each period in the model with a 25-percent down payment and the remainder financed with a 4-year loan. The only ownership charge associated with machinery investment is depreciation, calculated by using a 10-year double-declining-balance method with a 20-percent salvage value. Other detailed data on machinery investment are presented in Appendix Table 2.

**Feedlot**

Investments in feedlot capacity can be made in each year, with the lot available for cattle placements at the start of the year. Feedlot investment requirements are based upon a 300-head capacity open lot with shelter facility, which was estimated to cost $109,230 in 1979 (McGrann et al., 30, p. 12). Annual ownership costs include depreciation and repairs, taxes, and insurance. McGrann et al. (30, p. 21) provide rates for these charges, based upon the original purchase price. To compute current values for the feedlot, it was assumed that remaining values decline 7 percent per year. This factor was then adjusted for inflation with an index of building and fencing costs (U.S. Department of Agriculture, 48). Detailed data on the feedlot-investment activities are given in Appendix Table 3.

**Off-farm investments**

Rather than use liquid funds to purchase physical assets, the farmer can invest money off-farm. This investment carries an assured return of 8 percent.

**Financial Activities**

Investment activities, as well as production activities, may require the use of more funds than the firm can generate internally. Financial activities are included in the model so that outside funds can be used to augment internal cash flows.

Borrowing capacity is determined by the current value of assets held at the first of the year. In general, assets against which funds can be secured are land, machinery, and feedlot, but no provisions are made for borrowing against cash holdings, crop and feed inventories, or cattle in the lot. Borrowing up to 50 percent of fixed asset value is allowed.

7Other ownership costs are included in the costs associated with the producing of various crops.

8Normally a firm would be allowed to borrow against these assets, but incorporating these assets into the borrowing capacity of the firm would complicate the model structure. Because these items are in inventory for only part of the year and their value is small compared with that of fixed assets, their omission was not expected to seriously underestimate borrowing ability. Furthermore, borrowing capacity is not an effective constraint on growth for most of the model solutions.
Short-term credit

Short-term borrowings for 6-month periods are available to augment cash flows. Interest and principal payments on a loan obtained at the start of a period are due at the beginning of the succeeding period; principal payments, however, can be refinanced. The model is constructed so that short-term credit can be used to finance all or part of the required down payment on asset purchases.

Intermediate-term credit

Intermediate-term credit is used to finance 75 percent of both the purchase of farm machinery and the building of feedlot capacity. Interest rates on both types of loans are those for non-real-estate debt (see Appendix Tables 2 and 3). The only difference between the two loans is the repayment requirements. Machinery loans require repayment in four equal installments, and building loans are repaid in 7 years. Interest and principal payments are made at the end of the year.

Long-term credit

A long-term loan is used to finance 80 percent of the cost of land purchases. The loan must be repaid in 20 equal installments, with interest charged on the unpaid balance (see Appendix Table 1 for rates). Principal and interest are due at the end of the year, and no provisions are made for prepaying or delaying principal payments.

Production Activities

Production activities use the firm's assets to generate profits and cash flow. For the firm studied, possible production activities consist of crops and cattle feeding.

Crops

Possible crops include corn, corn silage, and soybeans. All three crops may be grown on the owned land, but only soybeans and corn may be grown on the rented land. A maximum of half of the total acreage may be planted to soybeans. Technical coefficients for crops were obtained from planning budgets prepared for northwestern Iowa (McGrann et al., 29) and are considered representative of production experiences in the area. Budgets used were prepared for 1978; hence, they are considered appropriate for the first year of the model. A summary of the base variable production costs, labor requirements, and expected yields is given in Appendix Table 4. Crop yields are projected to increase 1 percent per year in the model. Labor requirements are held constant throughout the planning period.

Crop yields are sufficiently variable that this source of risk had to be included in the model. Crop-growing activities transfer a fixed output into crop or feed equations, and then cattle-feeding or grain-marketing activities draw upon these equations. The procedure followed to incorporate yield variability was to add a cost of meeting a production deficit (if actual yields were below expected) to variable production expenses. If a surplus was produced, then revenues from the assumed sale of extra output were subtracted from production expenses. Yield data from Clay County, Iowa, for the years 1965 through 1977 were used in these calculations. Annual production costs adjusted for yield variability are presented in Table 4. Historical time series were used to estimate objective function values and variances so that yield variability is included as part of cost variability.

<p>| Table 4. Costs of Production Per Acre for Each Year of the Model. |
|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|</p>
<table>
<thead>
<tr>
<th>Perio Period</th>
<th>Owned Land</th>
<th>Rented Land</th>
<th>Owned Land</th>
<th>Rented Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>$ 99.08</td>
<td>$ 52.26</td>
<td>$ 97.76</td>
<td>$ 55.36</td>
</tr>
<tr>
<td>Year 2</td>
<td>105.22</td>
<td>55.48</td>
<td>103.06</td>
<td>58.90</td>
</tr>
<tr>
<td>Year 3</td>
<td>111.36</td>
<td>58.70</td>
<td>108.28</td>
<td>62.44</td>
</tr>
<tr>
<td>Year 4</td>
<td>117.50</td>
<td>61.90</td>
<td>113.68</td>
<td>65.98</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
<td>-------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
</tbody>
</table>

Cattle-feeding activities

Cattle-feeding activities consist of the following programs:

1. Steer feeding—Yearling feeder steers are purchased at 650 pounds and fed 150 days to 1,150 pounds. Net selling weight is 1,100 pounds. Steers can be placed during October, with sale the following July.

2. Heifer feeding—Feeder heifers are purchased at 550 pounds and fed approximately 150 days to 950 pounds. Net selling weight is 910 pounds. Like the steer-feeding program, heifers can be placed in February and August.

3. Steer calf feeding—Feeder calves are purchased at 450 pounds and fed approximately 9 months to 1,150 pounds. Net market weight is 1,100 pounds. Calves are placed during October with sale the following July.

Rations for all feeding programs consist of shelled corn, corn silage, and soybean oilmeal. Variability in feed conversion efficiency was not considered. Cattle-feeding activities were entered on a gross margin basis, with Omaha choice prices (U.S. Department of Agriculture, 48) used to determine cash purchasing and selling prices. Forecasted margins for the four years of the model are linear trend estimates using data from 1966-77. Cash margins for marketing strategies (to be discussed in detail later) are listed in Table 5. Actual margins for the years 1966-77 were used to calculate the covariance matrix. Labor requirements are 2.4 hours per head for the yearling steer and heifer programs and 4.0 hours per head for the steer calf program (McGrann et al., 30, p. 12). This labor requirement is divided evenly over time.

Marketing Activities

The basic model includes only cash purchases at the time an input is purchased with cash sale at the date output is sold. To determine the importance of market-
Grain-marketing strategies consist of cash market transactions or a combination of cash and futures market transactions. For both corn and soybeans, the following marketing activities are included:

1. Cash sales. Grain is harvested in October and then sold for cash. The cash sale may take place at harvest, or the grain may be stored and held for sale during one of the months of December, February, June, or August.

2. June-March hedge. A March futures contract is sold in June, after the crop has been planted. After harvest, the grain is stored until March, at which time the grain is sold on the cash market and an offsetting March futures contract is purchased.

3. August-June hedge. During August, a July futures contract specifying delivery during the following year is sold. After harvest, the grain is stored until June, at which time it is sold on the cash market and an offsetting July futures contract is purchased.

4. Storage hedge. During October when the grain is being harvested, a July futures contract is sold. The harvested grain is held until June, when it is sold and an offsetting July futures contract is purchased.

5. Harvest sale-futures purchase. Grain is sold for cash after harvest and a July futures contract is purchased. In June, an offsetting futures transaction is made. In effect, this strategy allows a farmer to store grain in the form of a futures contract rather than as a physical commodity.

Net sales prices for each of the 4 years of the model are summarized in Table 6. Prices and covariance coefficients were calculated by using actual net sales prices for 1966-77. All cash transactions are based on the monthly cash price for the month in which the sale is made. Net prices for strategies involving futures transactions were calculated by adding the profits or losses obtained in the futures market to the cash price at which the grain would have been sold. Monthly average futures prices ("Futures Prices," 13) were used.
Cattle-marketing activities

For the yearling steer and heifer programs, the following strategies are available in addition to the cash market plan previously discussed:

1. February-July hedge. During February when feeder animals are placed, an August futures contract is sold. An offsetting futures contract is purchased in July, near the date when slaughter animals are sold.
2. February-June hedge. This is the same as strategy 1 except that the offsetting futures purchase is made in June, a month before finished cattle are sold. Basis relationships may be more favorable at this time; i.e., the futures price may be considerably below the cash price compared with the delivery month when the two prices tend to be equal.
3. April-July hedge. This is the same as strategy 1 except that the August futures contract is not sold until April. The cattle are unhedged the first 2 months of the feeding period.
4. April-June hedge. Feeders placed in February are hedged in April, and the hedge is then lifted in June.
5. August-January hedge. Feeder animals are placed in August, and a February futures contract is sold. The hedge is maintained until the following January when slaughter animals are sold.
6. August-December hedge. This is the same as strategy 5 except that the hedge is placed during October when finished cattle are sold.
7. October-January hedge. This is the same as strategy 5 except that the February contract is not sold until October.
8. October-December hedge. August placements are not hedged until October, and the hedge is then lifted in December.

Similar strategies are available for the steer calf program. These consist of the following:

1. October-July hedge. A hedge, using the August futures contract, is placed during October when feeder calves are placed. This hedge is maintained until July, when the cattle are sold.
2. October-June hedge. This is the same as strategy 1 except that the offsetting purchase of the August futures contract is made in June.
3. December-July hedge. This is the same as strategy 1 except that the hedge is not placed until December.
4. December-June hedge. The August futures contract is sold in December, and an offsetting purchase is made in June.

Feeding programs were entered as gross margin activities; for each futures marketing strategy, an activity similar to the appropriate cash feeding program was included. Cash returns were augmented with the results of futures market transactions with average futures prices obtained by using Wednesday closing prices. Again, gross margins used for each year of the model are linear trend estimates using data from 1966-77 as summarized in Table 5. The covariance coefficients were calculated by using the same data.

Input-Purchasing Activities

Input-purchasing activities secure inputs that are consumed in the production process. These include labor services and feed supplies.

Labor services

Labor services can be purchased in the form of a full-time hired man who provides labor services in the same quantity as the operator (Table 2). Wage cost is based on a monthly rate of $750 in 1977 and adjusted for different years by using the USDA wage rate index (U.S. Department of Agriculture, 48).

Feed supplies

Purchased feed supplies consist of corn grain and soybean oil meal. Both input prices are yearly average prices. The corn price is a northwestern Iowa price while the soybean oil meal price is the average price paid by Iowa farmers (U.S. Department of Agriculture, 48).

Accounting Activities

Accounting activities account for family consumption and the payment of taxes. These activities determine the amount of profits that the firm has available for investment.

Consumption

A regression equation using family expenditure data collected by the Iowa Cooperative Extension Service (15) was used to estimate annual consumption. The equation obtained is:

$$ C = -37,416 + 619Y + 0.041 $$

where

- $C$ is the amount of consumption expenditures
- $Y$ is the last two digits of the year, and
- $I$ is income.

In the model, consumption is calculated from the intercept and the amount arising from the variable for the year. Fixed consumption is $10,864 in the first year, $11,484 in the second year, $12,104 in the third year, and $12,724 in the fourth year. Increases in consumption in response to income are combined with the tax rate.

$^{11}$The data were obtained from family living expenditure records kept by farm families throughout Iowa. Data for the years 1970, 1972, and 1974 were used to derive the regression equation.
Taxes and income-related consumption

It is assumed that taxes plus the marginal propensity to consume from income account for 50 percent of cash receipts less cash expenses, depreciation, and fixed consumption. The 50-percent figure is somewhat arbitrary, but it is consistent with rates used in other studies (Boehlje and White, 2; and Chen, 5).

EMPIRICAL RESULTS

This section reports the results obtained when a quadratic program was used to solve the model discussed in the previous section. These solutions suggest ways in which a farmer might organize his operation depending upon risk preferences. Two different models were solved. The first was the basic model, which includes only cash-marketing activities; the second model includes additional marketing options for crops and livestock.

Basic Model

The efficiency frontier for the basic model is shown in Figure 3. The numbers along the curve represent points for which solutions are discussed in greater detail. Legends along the frontier indicate points at which key changes occur in activities for the first year. Because risk aversion increases as one moves left along the frontier, solution (1) in Figure 3 represents the highest degree of risk aversion analyzed, and solution (10) represents a point of risk indifference.

Initially, this frontier displays a linear segment until point (2) is reached; after that, the curve becomes concave. Along the linear segment, solutions differ primarily in the amount of machinery and land held by the firm (the initial size) at the start of the planning horizon. Note that cattle are not included in the solution for the first year until midway on the frontier, solution (4).

The 4-year investment plan

Table 7 presents selected solution data for the 10 points enumerated on Figure 3. These solutions indicate investment plans that would be most efficient (in...
Table 7. Four-Year Investment Plan for the Basic Model.

<table>
<thead>
<tr>
<th>Solutions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5)</td>
<td></td>
<td>(6)</td>
<td></td>
</tr>
<tr>
<td>Terminal net worth ($)</td>
<td>502,684</td>
<td>1,244,761</td>
<td>1,278,718</td>
<td>1,322,641</td>
<td></td>
<td>1,370,873</td>
<td>1,314,035</td>
<td>1,458,269</td>
<td>1,680,966</td>
</tr>
<tr>
<td>Initial net worth ($)</td>
<td>310,782</td>
<td>707,086</td>
<td>712,452</td>
<td>712,452</td>
<td></td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
</tr>
<tr>
<td>Change in net worth ($)</td>
<td>191,902</td>
<td>537,057</td>
<td>566,266</td>
<td>620,189</td>
<td></td>
<td>658,421</td>
<td>701,583</td>
<td>745,817</td>
<td>768,314</td>
</tr>
<tr>
<td>Net worth change due to price appreciation ($)</td>
<td>172,951</td>
<td>426,455</td>
<td>442,354</td>
<td>497,350</td>
<td></td>
<td>524,024</td>
<td>549,329</td>
<td>576,475</td>
<td>572,767</td>
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<tr>
<td>Percent change due to price appreciation (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td>77</td>
<td>77</td>
<td>76</td>
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<tr>
<td>Standard deviation of terminal net worth ($)</td>
<td>9,960</td>
<td>24,559</td>
<td>25,370</td>
<td>27,183</td>
<td></td>
<td>28,870</td>
<td>31,854</td>
<td>36,221</td>
<td>40,181</td>
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<td>Land (acres)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Initial owned land</td>
<td>130</td>
<td>320</td>
<td>320</td>
<td>320</td>
<td></td>
<td>320</td>
<td>320</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>Farm Size - Year 1</td>
<td>130</td>
<td>320</td>
<td>320</td>
<td>320</td>
<td></td>
<td>320</td>
<td>562</td>
<td>589</td>
<td>628</td>
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<td>Farm Size - Year 2</td>
<td>130</td>
<td>320</td>
<td>384</td>
<td>389</td>
<td></td>
<td>474</td>
<td>491</td>
<td>493</td>
<td>532</td>
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<td>Farm Size - Year 4</td>
<td>130</td>
<td>320</td>
<td>382</td>
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<td>426</td>
<td>443</td>
<td>445</td>
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<td>Land rented - Year 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>237</td>
<td>190</td>
<td>225</td>
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<td>Land rented - Year 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>124</td>
<td>133</td>
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<td>Land rented - Year 3</td>
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<td>0</td>
<td>0</td>
<td></td>
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<td>48</td>
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<td>Land rented - Year 4</td>
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<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>56</td>
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<tr>
<td>Land purchased - Year 1</td>
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<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>5</td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td>Land purchased - Year 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>77</td>
<td>81</td>
<td>47</td>
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<tr>
<td>Land purchased - Year 3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>29</td>
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<tr>
<td>Land purchased - Year 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total land purchased</td>
<td>0</td>
<td>13</td>
<td>77</td>
<td></td>
<td></td>
<td>106</td>
<td>123</td>
<td>125</td>
<td>124</td>
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<tr>
<td>Feedlot Investment (head - capacity added)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Year 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>34</td>
<td>83</td>
<td>137</td>
<td>164</td>
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<tr>
<td>Year 2</td>
<td>113</td>
<td>279</td>
<td>270</td>
<td>280</td>
<td></td>
<td>235</td>
<td>235</td>
<td>203</td>
<td>209</td>
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<tr>
<td>Year 3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>23</td>
<td>0</td>
<td>58</td>
<td>186</td>
</tr>
<tr>
<td>Year 4</td>
<td>113</td>
<td>279</td>
<td>270</td>
<td>280</td>
<td></td>
<td>292</td>
<td>318</td>
<td>349</td>
<td>431</td>
</tr>
<tr>
<td>Total capacity added</td>
<td>113</td>
<td>279</td>
<td>270</td>
<td>280</td>
<td></td>
<td>349</td>
<td>431</td>
<td>559</td>
<td>813</td>
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<tr>
<td>Debt Utilization ($)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New borrowings - Year 1</td>
<td>27,741</td>
<td>27,328</td>
<td>27,487</td>
<td>27,480</td>
<td></td>
<td>39,964</td>
<td>67,159</td>
<td>275,897</td>
<td>310,506</td>
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<tr>
<td>New borrowings - Year 2</td>
<td>63,635</td>
<td>156,480</td>
<td>164,744</td>
<td>291,808</td>
<td></td>
<td>363,660</td>
<td>351,643</td>
<td>319,597</td>
<td>314,332</td>
</tr>
<tr>
<td>New borrowings - Year 3</td>
<td>44,783</td>
<td>91,509</td>
<td>93,966</td>
<td>162,790</td>
<td></td>
<td>214,734</td>
<td>233,204</td>
<td>158,857</td>
<td>201,867</td>
</tr>
<tr>
<td>New borrowings - Year 4</td>
<td>23,856</td>
<td>53,708</td>
<td>56,853</td>
<td>117,998</td>
<td></td>
<td>150,175</td>
<td>161,405</td>
<td>169,013</td>
<td>229,808</td>
</tr>
</tbody>
</table>
| All solutions indicate that net worth is expected to increase significantly over the 4-year planning horizon. The rate of increase for solution (1), the most risk-averse solution, is 61.7 percent; solutions with more risk show even higher rates of increase, with a 110.1 percent growth in net worth over time for solution (10). At higher levels of risk aversion, this gain is more a result of asset appreciation than of accumulated earnings. For example, in solution (1), 90.1 percent of expected net worth gain is attributed to asset appreciation. At lower levels of risk aversion, accumulated savings become a more important factor in net worth growth; in solution (10), for example, only 66.1 percent of the gain results from asset appreciation. Although data on expected land-value increases are not shown for each solution, this is the main source of capital gain additions to net worth. For example, in solution (5), land values are expected to appreciate $547,318, and in solution (10), appreciation in land values is expected to amount to $547,318. In both cases, the amount of increase in land values is greater than total capital gains; the reason is that machinery values decline with time, thereby partly offsetting increases in land values.

Land and machinery

The land base consists of acreage owned at the beginning of the planning period, rented land (a maximum of 320 crop acres or 341.3 actual farm acres), and land purchases during the planning horizon. Solution (1) indicates that a farmer who is highly averse to risk would operate a very small farm; total acreage is only 130 acres, and additional land purchases are not made nor is land rented during the planning horizon. As risk aversion decreases, farm size increases, with farm acreage in year 4 expanding steadily to a maximum of 586 acres in solution (9). In solutions (1) and (2), the size of the cropping operation is not increased over time beyond that initially owned. Beginning with solution (3), however, the farm is expanded over time by using both purchasing and rental options. Generally, peak acreages occur in the second or third years for solutions (3) through (5). Acreage declines in the later years for these solutions terms of means and variances) for a farmer, given his present knowledge of the future. In reality, investments for the second through fourth years may not actually be made because results for the first year likely would not occur exactly as expected. At the end of the first year, a farmer would revise his investment plan on the basis of actual performance and new information. Results for the 4 years are provided to show the initial estimate of the dynamic growth path.
because purchased land is being substituted for rented land. Purchased land requires more capital and injects more variability into net worth than does rented land; hence, fewer acres are farmed. In solutions (6) through (10), acreage farmed shows an overall decline throughout the horizon. This is caused by the addition of rented land during the first year and the substitution of purchased land for rented land in later years. Again, purchased land is used on a smaller scale than is rented land.

The stock of machinery owned each year is determined by two factors: the amount of land farmed and the amount of obsolete machinery removed from the original inventory each year. Thus, machinery purchases are made to adjust to increases in farm size and to replace items that are no longer reliable. Although not shown in the table, machinery stock follows the same adjustment pattern as that noted for farm acreage.

**Feedlot capacity**

At high levels of risk aversion, i.e., solutions (1) through (4), no feedlot capacity is built during the first year. Feedlot capacity is added in the second year, increasing from 113 head in solution (1) to 280 head in solution (4), but no further capacity expansions are planned in either the third or fourth year.

In solution (5), a 34-head capacity feedlot is built in the first year, and total capacity throughout the 4-year horizon is increased to 292 head. In solutions (6) through (10), cattle feeding becomes a more significant part of the farm operation as total capacity additions during the 4 years amount to 318 head for solution (6) and increase to 813 head for solution (10). In moving from solution (9) to (10), a significant increase—254 head—occurs in total feedlot capacity built during the planning horizon.

Financial

In general, declining risk aversion is reflected in more use of debt; in solutions (1) through (7), use of borrowed money becomes increasingly more extensive as the scale of farming operations increases. Total new borrowings throughout the horizon amount to $297,150 in solution (3) and $923,364 in solution (7). Additional borrowings, however, would be possible in all years, with the exception of the second year in solutions (5) through (7). In solutions (8) through (10), unused borrowing capacity is steadily reduced, and borrowing increases until capital becomes a limiting factor throughout the horizon in solution (10). Off-farm investments are made in the first year of solutions (1) through (5), ranging in amount from $44,000 to $50,000. In solutions (1) and (2), off-farm investments of $26,000 to $34,000 also are made in the third year.

Labor

At high levels of risk aversion, little or no outside labor is required. Labor is first hired in solution (5) during the second and third years. In solutions (5) through (8), peak hirings occur in the second year of the horizon. In these solutions, acreages farmed during the third and fourth years decline sufficiently to reduce labor requirements (cattle feeding expands little or not at all after the second year). In solutions (9) and (10), labor hirings remain fairly stable over time, fluctuating between 0.4 and 0.6 man per year.

**First-year production plan**

Table 8 presents information on the cropping and livestock production plan for the first year of the basic model. Data are provided for the same solutions presented in Table 7.

As risk aversion decreases, crop acres in the first year increase from 122 acres in solution (1) to 684 acres in solution (10). These figures are the sum of all planned new borrowings during the 4-year horizon.

Table 8. The First Year Production Plan for the Basic Model.

<table>
<thead>
<tr>
<th></th>
<th>Solutions</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
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<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
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<tr>
<td>Total crop acres</td>
<td>122</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>527</td>
<td>553</td>
<td>588</td>
<td>684</td>
</tr>
<tr>
<td>Total cattle fed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>34</td>
<td>166</td>
<td>274</td>
<td>329</td>
<td>335</td>
</tr>
<tr>
<td>Crop plantings (acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn grain</td>
<td>68</td>
<td>168</td>
<td>168</td>
<td>169</td>
<td>164</td>
<td>292</td>
<td>313</td>
<td>282</td>
<td>292</td>
</tr>
<tr>
<td>Corn silage</td>
<td>17</td>
<td>41</td>
<td>42</td>
<td>43</td>
<td>42</td>
<td>50</td>
<td>53</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Soybeans</td>
<td>37</td>
<td>91</td>
<td>90</td>
<td>89</td>
<td>94</td>
<td>185</td>
<td>187</td>
<td>257</td>
<td>342</td>
</tr>
<tr>
<td>Cattle program (head)a/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearling Steers - February</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>164</td>
<td>167</td>
</tr>
<tr>
<td>Yearling Steers - August</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yearling Heifers - February</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>137</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Steer Calves - October</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>34</td>
<td>83</td>
<td>137</td>
<td>164</td>
<td>167</td>
</tr>
</tbody>
</table>

a/ The month indicates the time of placement.
in solution (9). No cattle appear before solution (5) in which 34 head are fed during the first year. Further decreases in risk aversion lead to more cattle feeding until a plateau of approximately 330 head is reached in solution (8).

Heavy emphasis on soybeans is avoided at high levels of risk aversion because of the greater variability of soybean prices compared with corn. Soybeans do not account for the maximum allowable 50 percent of crop acreage on owned land until solution (6), and, on rented land, maximum soybean acreage is planted only in solution (9).

The cattle feeding program shows some major changes as risk aversion decreases. In solutions (1) through (4), no cattle are fed; then in solution (5) placements of October steer calves are begun. In solutions (6) and (7), February heifers are added to fill the lot during the first half of the year. In solutions (8) through (10), yearling steers instead of heifers are fed in the first part of the year; however, steer calves still are fed in the last half of the year.

**Marketing Model**

Because the complete marketing model was too large to be solved by the computer package efficiently, all marketing activities except the cash strategies used in the basic model were initially eliminated from the second through fourth years. This sufficiently reduced the size of the model so that a complete parametric run could be made. Because the covariance matrix is independent among years, marketing activities that appeared in the first year likely would be used in subsequent years.

An analysis of the first-year marketing results showed that only one or two marketing strategies were used for each crop or livestock product for most solutions; therefore only those marketing activities used with any frequency throughout the frontier were retained. Marketing activities similar to those dominant in the first year were then specified for the second through fourth years. In the final run of the marketing model, the following marketing activities were used in each of the 4 years:

1. Corn
   - June-March hedge
   - August-June hedge
2. Soybeans
   - June-March hedge
   - Cash sale in June
3. February yearling steers
   - April-June hedge
   - April-July hedge
4. August yearling steers
   - October-December hedge
5. February heifers
   - April-July hedge
6. October calves
   - Cash sale
   - October-June hedge

Figure 4 shows the efficiency frontier for the marketing model. Similar to earlier results, this efficiency frontier also is linear until solution (2) is reached; in this range, solutions differ primarily in initial ownership of land and machinery. In this model, however, cattle are fed during the first year throughout the entire frontier, which is quite different from the basic model.

**The 4-year investment plan**

Table 9 presents selected data for the 10 solution levels shown in Figure 4. In moving from solution (1) to solution (5), terminal net worth increases 112 percent while the standard deviation of net worth increases 145.5 percent. In contrast, in moving from solution (5) to (10), terminal net worth increases only 6.4 percent while the standard deviation increases 78.7 percent. Increases in wealth can be achieved in this part of the frontier only if one is willing to accept rather large increases in net worth variability.

All solutions show significant increases in net worth over the 4-year planning horizon. Even the most risk-averse solution shows a 76.7 percent improvement in net worth; the largest increase occurs in solution (10) in which terminal net worth increases by almost 120 percent over initial net worth. For all solutions, net worth improvement is largely a result of appreciation in the value of owned assets.

**Land and machinery**

As in the basic model, risk aversion is clearly reflected in the size of farm operated. At the highest level of risk aversion, solution (1), farm acreage in year 4 is only 207 acres. In moving to a midpoint on the frontier, solution (5), farm size in year 4 increases to 453 acres.

From solutions (5) through (10), farm size in year 4 increases to 697 acres. These results strongly suggest that decreases in risk aversion allow an increase in farm size.

In all solutions, acreage is added to the farm during the planning horizon. In solutions (1) and (2), land expansion consists of small amounts of both rented and purchased land in the second and third years. Beginning with solution (3), land rental is undertaken in the first year, and in that and all subsequent solutions,
Figure 4. Efficiency frontier for the marketing model.

Table 9. Four-Year Investment Plan for the Marketing Model.

<table>
<thead>
<tr>
<th>Solutions</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal net worth ($)</td>
<td>691,646</td>
<td>1,312,018</td>
<td>1,254,458</td>
<td>1,430,021</td>
<td>1,666,476</td>
<td>1,497,103</td>
<td>1,529,572</td>
<td>1,243,958</td>
<td>1,553,694</td>
<td>1,360,772</td>
</tr>
<tr>
<td>Initial net worth ($)</td>
<td>391,367</td>
<td>705,035</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
<td>712,452</td>
</tr>
<tr>
<td>Change in net worth ($)</td>
<td>300,279</td>
<td>606,983</td>
<td>642,005</td>
<td>717,569</td>
<td>714,024</td>
<td>784,651</td>
<td>817,120</td>
<td>831,506</td>
<td>841,248</td>
<td>848,320</td>
</tr>
<tr>
<td>Terminal net worth change due to price appreciation ($)</td>
<td>236,793</td>
<td>489,018</td>
<td>514,593</td>
<td>544,045</td>
<td>557,868</td>
<td>560,264</td>
<td>557,967</td>
<td>564,697</td>
<td>565,950</td>
<td>556,581</td>
</tr>
<tr>
<td>Percent change due to price appreciation (%)</td>
<td>85</td>
<td>81</td>
<td>80</td>
<td>76</td>
<td>74</td>
<td>71</td>
<td>68</td>
<td>68</td>
<td>67</td>
<td>66</td>
</tr>
<tr>
<td>Standard deviation of terminal net worth ($)</td>
<td>11,144</td>
<td>21,092</td>
<td>21,894</td>
<td>24,845</td>
<td>27,357</td>
<td>30,466</td>
<td>35,303</td>
<td>38,666</td>
<td>42,690</td>
<td>48,881</td>
</tr>
</tbody>
</table>

Land (acres)
- Initial owned land: 169
- Farm Size - Year 1: 169
- Farm Size - Year 2: 244
- Farm Size - Year 3: 255
- Farm Size - Year 4: 207

Land rented:
- Year 1: 0
- Year 2: 49
- Year 3: 19
- Year 4: 0

Land purchased:
- Year 1: 0
- Year 2: 26
- Year 3: 12
- Year 4: 38

Total land purchased: 147

Feedlot investment:
- Head - capacity added
  - Year 1: 132
  - Year 2: 0
  - Year 3: 15
  - Year 4: 0

Total capacity added: 167

Debt Utilization ($)
- New borrowings - Year 1: 36,209
- New borrowings - Year 2: 101,487
- New borrowings - Year 3: 68,463
- New borrowings - Year 4: 80,470

New borrowings - Year 3: 38,085
New borrowings - Year 4: 135,745
land rental is greatest in the first 2 years and declines rather sharply in years 3 and 4. For example, in solution (5), 265 acres are rented in the first year, but no land is rented in the fourth year. This pattern of land rental causes overall acreage farmed to decline over the 4-year period for solutions (3) through (10). In some cases, the decline shown is rather large; e.g., in solution (5), the reduction amounts to 144 acres or 24.1 percent of the acreage farmed in the first year. The decline in total acreage farmed again seems to be the result of purchased land being substituted for rented land; the firm cannot maintain the same size acreage with purchased land that it can when more reliance is placed on rented land.

Land purchases total 38 acres in solution (1), increase to a maximum of 152 acres in solution (9), then fall to 132 acres in solution (10). This decline in land purchases between the last two solutions seems to be a result of a significantly greater emphasis on cattle feeding as feedlot capacity in the fourth year increases 184 head between solutions (9) and (10). The amount of machinery stock owned in each year closely parallels the amount of acreage farmed.

Feedlot investment

Cattle feeding is feasible beginning the first year throughout the entire frontier. Even for the highest level of risk aversion studied, solution (1), feedlot space for 132 head is built in the first year. As risk aversion decreases, feedlot investment during the first year increases rapidly, reaching a peak of 326 head in solution (5). In solutions (1) through (5), additional investments in feedlot capacity are made in the third year. Generally, these investments are much smaller than those made in the first year; in solution (1), capacity is increased only 15 head, or 11 percent, in year 3, and in solution (5), 90 head of capacity is added, a 27.6-percent increase.

In moving from solution (5) to solution (6), feedlot capacity built in the first year is reduced 110 head. To offset this, capacity is added in the second year and increased in the third year, resulting in an increase of 19 head in total ending capacity compared with solution (5). From solutions (5) to (8), capacity in year 4 increases only 50 head, but land purchases also are being increased. In this part of the frontier, the expansion is diversified between land and cattle. Finally, in moving from solution (8) to (10), total feedlot investment increases 225 head while total land purchases decline 19 acres. In this part of the frontier, feedlot investments dominate land investments.

Financial

The data on borrowing activities indicate that risk aversion again is associated with the conservative use of credit. In solutions (1) through (3), credit is not used extensively, and rather large sums of additional money, ranging from $100,000 to $300,000, can be borrowed in each year. In solutions (4) through (10), large investments in land and feedlot facilities cause unused borrowing capacity to be steadily reduced. The total of new borrowings throughout the horizon increases from $961,700 in solution (4) to $1,451,566 in solution (10). Capital does not become restrictive throughout the horizon until solution (10). Off-farm investments are not made in any solutions.

Labor

At high levels of risk aversion, no outside labor is hired. Beginning with solution (4), labor is hired in all 4 years, with a maximum of 0.8 hired man in the last 2 years of solution (10). In these solutions, labor demands during spring planting create the need for hired labor in all 4 years of the planning horizon. In the last 2 years of the horizon, less labor is needed for crops, but this is offset by the need for more labor to feed cattle. Consequently, more labor is hired in the last 2 years of the horizon than in the first 2 years for solutions (4) through (10).

First-year production and marketing plan

Table 10 shows selected data for the cropping and livestock plan for the first year of the marketing model. The solutions summarized are for the same net worth levels as those listed in Table 9. As risk aversion decreases, total crop acreage increases rapidly until solution (6); for less risk-averse solutions (7) through (10), first-year plantings fluctuate between 676 and 686 acres. Risk aversion also affects crops planted and the choice of marketing activities. Solutions (1) through (3) do not include any soybean acreage, and soybean production does not account for the maximum allowable half of crop acres until solution (6). Clearly, a farmer who wants to avoid risk would not want to emphasize soybean production.

Peak corn production of 373 acres occurs in solution (3), with the crop plan consisting of only corn grain and corn silage. In solution (4), 150 acres of soybeans are planted, and corn acreage drops by 118 acres. In subsequent solutions, soybean production is steadily increased until a plateau of about 340 acres of production is attained in solutions (7) through (10). In solutions (7) through (10), corn grain production fluctuates between 290 and 310 acres, and silage accounts for 30 to 50 acres. Silage production declines after solution (8) because feedlot capacity added during the first 2 years is reduced, and fewer cattle are being fed in the second year (Table 9).

In solutions (1) through (3), approximately 75 percent of corn production is marketed by using the June-March hedge, and the rest is fed to cattle. All corn produced is fed to cattle in solutions (4) through (8). In solutions (9) and (10), corn again is sold, but the August-June hedge is used. In solution (10), 41 percent of the corn grain, or 10,330 bushels, is sold by using the August-June hedge.

Soybean marketing activities also change as risk preferences change. In solutions (4) and (5), all soybeans are sold by using the June-March hedge. Then in solutions (6) and (7), the riskier activity of selling soybeans for cash in June begins to replace the hedging option. In solutions (8) through (10), June cash sales are totally dominant.

For high levels of risk aversion, solutions (1)
Table 10. The First Year Production and Marketing Plan for the Marketing Model

<table>
<thead>
<tr>
<th>Solutions</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total crop acres</td>
<td>159</td>
<td>300</td>
<td>405</td>
<td>448</td>
<td>560</td>
<td>662</td>
<td>678</td>
<td>677</td>
<td>676</td>
<td>686</td>
</tr>
<tr>
<td>Total cattle fed</td>
<td>187</td>
<td>351</td>
<td>372</td>
<td>506</td>
<td>597</td>
<td>430</td>
<td>331</td>
<td>353</td>
<td>377</td>
<td>326</td>
</tr>
<tr>
<td>Crop plantings (acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn grain</td>
<td>141</td>
<td>267</td>
<td>373</td>
<td>255</td>
<td>305</td>
<td>283</td>
<td>290</td>
<td>289</td>
<td>298</td>
<td>310</td>
</tr>
<tr>
<td>Corn silage</td>
<td>37</td>
<td>33</td>
<td>32</td>
<td>43</td>
<td>48</td>
<td>48</td>
<td>49</td>
<td>49</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Soybeans</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>150</td>
<td>206</td>
<td>331</td>
<td>339</td>
<td>338</td>
<td>338</td>
<td>343</td>
</tr>
</tbody>
</table>

| Disposition of corn (bushels) | | | | | | | | | | |
| Fed to cattle | 3,829 | 7,757 | 9,277 | 19,898 | 22,686 | 22,371 | 23,088 | 23,040 | 18,739 | 14,998 |
| Sold June-March hedge | 11,708 | 21,662 | 26,005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sold August-June hedge | 0 | 0 | 0 | 5,194 | 10,330 | 10,330 | 10,330 | 10,330 | 10,330 | 10,330 |

| Disposition of soybeans (bushels) | | | | | | | | | | |
| Sold June-March hedge | 0 | 0 | 0 | 6,000 | 7,241 | 927 | 0 | 0 | 0 | 0 |
| Sold in June - cash | 0 | 0 | 0 | 0 | 0 | 0 | 1,816 | 0 | 0 | 0 |
| Total soybeans | 0 | 0 | 0 | 6,000 | 7,241 | 10,038 | 10,361 | 10,337 | 10,313 | 10,511 |

| Cattle (head) | | | | | | | | | | |
| Yearling Steers - February | | | | | | | | | | |
| Sold April-June hedge | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sold April-July hedge | 0 | 0 | 0 | 0 | 95 | 216 | 179 | 184 | 188 | 0 |
| Yearling Steers - August | | | | | | | | | | |
| Sold October-December hedge | 54 | 100 | 125 | 189 | 271 | 214 | 131 | 112 | 91 | 0 |
| Yearling Heifers - February | | | | | | | | | | |
| Sold April-July hedge | 132 | 251 | 247 | 317 | 231 | 0 | 0 | 0 | 0 | 0 |
| Steer Calves - October | | | | | | | | | | |
| Sold cash | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 97 | 163 | 163 |

*The month indicates the time of placement.*

frontier for the marketing model is more favorable to a farmer, with the gains greatest at higher levels of risk aversion. For example, in moving from point (2) on the frontier for the basic model (EF<sub>b</sub>) to point (2) on the marketing model frontier (EF<sub>M</sub>), expected net worth is increased 5.4 percent while the standard deviation declines 14.1 percent. Comparing solutions (8), a move from EF<sub>b</sub> to EF<sub>M</sub> increases net worth 4.3 percent while the standard deviation decreases only 3.8 percent.

**Net worth**

As indicated by evaluating comparable solutions from Tables 7 and 9, the use of hedging strategies allows the farmer to both increase expected wealth and reduce variability. Maximum improvement in expected wealth occurs between solutions (1)—a 37.6 percent increase. Reductions in net worth variability are most pronounced at high levels of risk aversion.

With the marketing model, asset appreciation generally is less important as a source of net worth growth, particularly in the middle of the frontier. Comparing solutions (6), the basic model achieves 77 percent of its increase in wealth from asset appreciation.

**Comparison of the Two Models**

This section highlights the impact that the use of hedging strategies can have on optimal farm plans. Figure 5, which shows the efficiency frontiers for both models, indicates that the frontier for the marketing model is rotated outward from the frontier of the basic model in a nonparallel fashion. The replacement of cash marketings with hedging strategies has changed the distribution of returns on grain and livestock production and thus caused the shift in the frontier. The
Figure 5. Efficiency frontier for the basic model (EF_B) and the marketing model (EF_M).

while the comparable figure for the marketing model is 71.4 percent. Both models show two-thirds of net worth growth coming from asset appreciation in solution (10).

Four-year investment plans

Addition of hedging activities to reduce risk clearly allows the farmer to operate a large size farm. Again, when data from Tables 7 and 9 are examined at comparable solutions, more land is operated with the marketing model in almost all years; never is farm acreage smaller in the marketing solutions. Farm acreage is larger in the marketing model because more rented and purchased land is farmed. From 12 to 74 more acres are purchased throughout the horizon when hedging strategies are utilized, with larger differences occurring in the less risk-averse solutions. Because the marketing model includes more acres, it also requires the use of a larger machinery stock.

Differences in feedlot investments tend to be less pronounced than for land, although with the marketing model, more feedlot investment is typically made in the first year. The exception occurs at solutions (10) in which a farmer who uses only cash marketings would build a slightly larger (5 head) feedlot in the first year. For the 4-year period, about one-third more feedlot capacity is added in the marketing model for solutions (4) and (6). In solution (2), total feedlot investment is 6 head larger in the basic model, and in solution (10), the basic model includes 120 more head capacity at the end of the planning horizon.

The data on borrowings show that hedging and diversified marketing allow a farmer to assume larger financial risk. Borrowing capacity is always more heavily used when hedging strategies are available, and this translates into the use of more borrowed money in all solutions except (10). For example, total new borrowings are 15.3 percent ($163,000) greater in the marketing model at solutions (8). In comparing borrowings at solution (4), there is a difference of $342,624, which translates into a 55-percent greater use of credit with the marketing model. Off-farm investments are included only in the more risk-averse basic model solutions, primarily during the first year (about $50,000).

More labor tends to be hired in the marketing model since more land is farmed. As noted previously, time requirements needed for spring planting create the need for outside assistance in both models.

Differences in first-year production plans

At both the highest and lowest levels of risk aversion, both models include about the same amount of cropland in the first year; the marketing model, however, includes 148 more acres in solution (4) and 135 more acres in solution (6) than does the basic model. In general, most of the corn produced is fed to cattle in both models, although more corn is sold as grain in the marketing model. With the exception of solutions (1) through (3) and (9), the marketing model provides a higher volume of soybean sales. For all solutions, the marketing model generates more revenue from crop sales.

Cattle placements during the first year are much higher in the marketing model except at solutions (10).
When feeding programs at solutions (6) are compared, the marketing model shows specialization in yearling steers, and the basic model has heifers placed in February followed by steer calves in October. In solutions (8), the programs became more similar as both models place only yearling steers in February; however, the marketing model feeds both yearling steers and steer calves in the last half of the year. At solutions (10), both models feed February yearling steers and October steer calves.

Implications

In general, the addition of hedging strategies and diversified marketing provides a farmer with the option of choosing a farm organization with both higher expected net worth and lower variability than if just cash marketings are used. The most noticeable changes are that more aggressive land use and financial plans can be followed. In some cases, the addition of marketing activities allows farm acreage to be increased as much as 50 percent. Also, in comparing total new borrowings, credit use is as much as 55 percent greater in the marketing model.

Differences in the cattle program are not as pronounced, although cattle feeding in the marketing model tends to be larger in the first year. In addition, cash grain sales seem to be a more important source of net worth growth in the marketing model than in the basic model.

SUMMARY

This study was undertaken to determine ways in which a cattle feeder could cope with risk. A cattle feeder was analyzed for two reasons: (1) Cattle feeding is an important enterprise in Iowa, particularly in the northwestern part of the state; and (2) cattle feeding is recognized as one of the riskier agricultural activities. One of the major sources of risk in agriculture is price variability, and in recent years, this has become even more critical. This model focuses on risk arising from fluctuations in crop and cattle prices and variation in crop yields. A farmer is allowed to manage risk through the choice of investment, financial, production, and marketing strategies. Thus, considerable latitude in managing risk was allowed; e.g., an extremely cautious investment plan or financing could be followed so that a riskier production plan could be adopted. The most flexibility allowed was in marketing activities to determine if such options would allow riskier production or investment plans.

A review of the literature suggested that maximization of expected utility would be the best method to use in analyzing decision making under uncertainty. Since the expected utility problem could be transformed into a mean-variance analysis, quadratic programming was used to solve the numerical model. A multiperiod model was constructed to provide a more accurate evaluation of future flows of services from investments. Likewise a net worth objective function, incorporating terminal asset values, was used to reflect appreciation in asset values.

The model was developed for a representative farm in northwestern Iowa. Options that a farmer could choose among included: (1) investment in land, machinery, feedlot capacity, and financial assets; (2) production of corn, soybeans, and slaughter cattle; and (3) a number of cash and futures marketing activities for produced commodities. Although secondary sources were used to derive technical coefficients, the model sufficiently reflects reality so that prescriptive, meaningful results were obtained. The solutions generated suggest ways in which a farmer might structure his operation, depending upon his attitude toward risk.

Two different models were solved, the basic model, which included only cash marketings, and the marketing model, which included additional marketing strategies such as hedging. Key results from these models are:

1. Increases in risk aversion require decreases in farm size; this reduction in size is evidenced by a decline in acreage farmed and fewer cattle being fed. Scale adjustments are larger at high levels of risk aversion. By using the marketing model as an example, when we move from the least risk-averse solution, solution (10), to a point midway on the frontier, solution (5), ending net worth declines 6.0 percent, ending farm acreage declines 35 percent, planned feedlot investment declines 40 percent, and total new borrowings decline 24.2 percent. In moving from solution (5) to the most risk-averse solution, solution (1), ending net worth declines 52.8 percent, ending farm acreage declines 54.3 percent, planned feedlot investment declines 64.7 percent, and total new borrowings decline 72 percent.

2. Risk aversion also is reflected in aversion to debt. At high levels of risk aversion, considerable amounts of additional funds could have been borrowed (as much as $300,000 in some years). As risk aversion decreases from the highest levels analyzed, the asset base of the firm gets larger, which, in turn, increases borrowing ability. However, while borrowing ability is increasing in absolute amounts, the amount of unused borrowing capacity declines. By using the marketing model as an example, total credit obtained throughout the horizon amounts to $307,629 in solution (1), $1,100,010 in solution (5), and $1,451,566 in solution (10). Borrowing ability is a limiting resource at some of the higher risk solutions.

3. At lower levels of risk aversion, solutions (5) through (10), modest improvements in wealth are possible if one is willing to expand both acreage and cattle-feeding operations. These increases in net worth, however, are costly in terms of variability—in comparing solutions (8) and (10) when only cash marketings are possible, net worth increases only 1.1 percent while the standard deviation of net worth increases 25.6 percent.

4. The introduction of additional marketing activities such as hedging has several effects upon farm organization. The most obvious is that it allows more aggressive investment and production strategies. At comparable solutions, from 12 to 74 more acres are purchased throughout the planning horizon, and farm acreage is never smaller when hedging strategies are
available. At high levels of risk aversion, the added marketing activities allow up to 60 percent more acres to be farmed. The higher acreages farmed allow a farmer to produce more cash-grain crops.

5. Total feedlot investment often is higher when only cash sales are allowed; when hedging strategies are available, however, feedlot capacity is expanded earlier so that more cattle generally are fed throughout the entire 4-year horizon. Because of the larger investments in land as well as greater crop and livestock production, more credit is used when hedging strategies are available. At higher levels of risk aversion, total borrowings over 4 years in the marketing model are almost double borrowings in the basic model, yet the variability of net worth is lower with the marketing model.

6. The additional marketing strategies provide more benefits in managing risk for highly risk-averse farmers than they do for those more indifferent to risk. For example at solutions (2), the marketing model results in a 5.4-percent increase in ending net worth and a 14.1-percent reduction in the standard deviation compared with the basic model. In contrast, at higher-risk solutions, solutions (8), the marketing model has a 4.3-percent higher net worth, but the standard deviation is lowered only 3.8 percent.

7. Maximum net-worth growth over the horizon requires a high level of cattle feeding compared with solutions offering slightly lower terminal net worth. In the basic model, movement from solution (9) to solution (10), the highest risk solution, requires a 254-head-larger feedlot investment (over 4 years) to obtain an increase of only $5,872 in terminal net worth. This modest improvement (0.4 percent) necessitates a 16.2-percent increase in the standard deviation. In the marketing model, movement from solution (9) to (10) requires a 184-head-larger feedlot investment (over 4 years) and the purchase of 20 fewer acres. Ending net worth increases only $7,078 (0.5 percent), but the standard deviation of net worth increases 14.5 percent in this case. At low levels of risk aversion, the cropping and livestock programs are quite competitive for available funds, but rather major shifts in the farming operation (for example, large increases in cattle feeding) increase terminal net worth only marginally. These slight increases in net worth require that a farmer be willing to accept a substantial increase in variability.

8. Risk aversion in the cropping programming requires emphasis on corn production. When additional marketing strategies are available, highly risk-averse farmers would prefer using the June-March hedge to cash sales of corn. For those more indifferent to risk, the August-June hedge is indicated to be a more desirable marketing tool.

9. At high levels of risk aversion, no more than 30 percent of crop acreage is planted to soybeans when only cash marketings are possible. When hedging strategies can be used, corn production is substituted for soybeans, and no soybean acreage is planted at high levels of risk aversion. When soybeans are grown in a marketing model solution, the June-March hedge is shown to be a less risky selling option. Maximum soybean acreage (50 percent of cropland) is planted and sold for cash in June when risk is not a major concern to a farmer.

10. Land investments do not totally dominate investments in cattle-feeding activities. In both models, feedlots are built throughout the frontier. Thus, cattle feeding is compatible with grain production for farmers willing to take even limited risk.

11. As to cattle production, risk-averse farmers should place heifers in February and yearling steers in August. For one less averse to risk, the February yearling steer and October steer calf programs are more desirable.

12. The most attractive cattle-marketing strategies are (1) an April-July hedge for February yearling steers except at high-risk solutions when the April-June hedge is used, (2) an October-December hedge for August yearling steers, (3) an April-July hedge for February heifers, and (4) cash sales for October steer calves.

13. Others have shown that risk aversion leads to a diversified marketing program for cattle feeders; i.e., it is desirable to market a given lot of cattle by using several different selling strategies (Leuthold, 22, pp. 22-24). In this study, little diversification in marketing of cattle (or grain) is suggested inasmuch as farmers seem to substitute scale adjustments (i.e., varying the level of planned investments and the amount of credit used) for market diversification in managing risk.

REFERENCES


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**APPENDIX**

Appendix Table 1. Investments in Land (Per Acre)

<table>
<thead>
<tr>
<th>Time of Purchase</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
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<tr>
<td>Terms:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Purchase price (dollars)</td>
<td>2,065</td>
<td>2,380</td>
<td>2,661</td>
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<tr>
<td>Downpayment (dollars)</td>
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<td>476</td>
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<td>Mortgage (dollars)</td>
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<td>Interest rate (percent)</td>
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Year end values (dollars):

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
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<tr>
<td>2,380</td>
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<td>-----</td>
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<tr>
<td>3,034</td>
<td>3,034</td>
<td>3,034</td>
<td>3,034</td>
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<tr>
<td>3,431</td>
<td>3,431</td>
<td>3,431</td>
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Appendix Table 2. Investments in Machinery (Per One Dollar of Machinery Capital)

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<th>Year 3</th>
<th>Year 4</th>
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</thead>
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<tr>
<td>Terms:</td>
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<td></td>
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<tr>
<td>Purchase price (dollars)</td>
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<td>1.1</td>
<td>1.21</td>
<td>1.34</td>
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<tr>
<td>Downpayment (dollars)</td>
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<td>0.275</td>
<td>0.303</td>
<td>0.335</td>
</tr>
<tr>
<td>Amount financed (dollars)</td>
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<td>0.825</td>
<td>0.9075</td>
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<tr>
<td>Interest rate (percent)</td>
<td>9.4</td>
<td>9.6</td>
<td>9.8</td>
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Depreciation (dollars):

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<th>Amount in Year 1</th>
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<th>Amount in Year 3</th>
<th>Amount in Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.16</td>
<td>0.128</td>
<td>0.1024</td>
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Year end values (dollars):

<table>
<thead>
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<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6257</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>0.8181</td>
<td>0.6888</td>
<td>------</td>
<td>------</td>
</tr>
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<td>0.6103</td>
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<td>0.6027</td>
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Appendix Table 3. Investments in Feedlot (300 head capacity).

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<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price (dollars)</td>
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<td>127,366</td>
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<td>Downpayment (dollars)</td>
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<td>27,308</td>
<td>29,416</td>
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<tr>
<td>Amount financed (dollars)</td>
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<td>81,922</td>
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<td>95,524</td>
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<tr>
<td>Interest rate (percent)</td>
<td>9.4</td>
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<td>9.8</td>
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</table>

Depreciation (dollars):

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<th>Amount in Year 1</th>
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<tr>
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Year end values (dollars):[8]

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<td>101,483</td>
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<td>------</td>
</tr>
<tr>
<td>101,959</td>
<td>101,437</td>
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<tr>
<td>102,453</td>
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<td>102,569</td>
<td>------</td>
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<tr>
<td>102,991</td>
<td>102,569</td>
<td>102,137</td>
<td>102,705</td>
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Appendix Table 4. Summary of Base Crop Budgets (Base Year, 1978).

<table>
<thead>
<tr>
<th>Corn Grain</th>
<th>Corn Silage</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable costs (dollars)</td>
<td>84.88</td>
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<tr>
<td>Labor requirements (hours)</td>
<td>2.079</td>
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<tr>
<td>Production</td>
<td>110 bu.</td>
<td>55 bu.</td>
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</table>

[8] Year end values are calculated by multiplying the original cost of the lot by a remaining value figure. This product is then adjusted for inflation with the USDA building and materials cost index (U.S. Department of Agriculture, 48).

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87/Year end values are obtained by multiplying purchase price by remaining value factors and then adjusting for inflation with the USDA farm machinery price index (U.S. Department of Agriculture, 48).