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Two articles employing risk programming techniques to determine optimal enterprise combinations on southern Iowa farms

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to determine optimal enterprise combinations

on southern Iowa farms

by

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TABLE OF CONTENTS

Page

GENERAL INTRODUCTION 1

Explanation of Thesis/Dissertation Format 2

Review of Risk Programming Literature 3

SECTION I. POSITIVE ANALYSIS AND NORMATIVE PROBLEMS: THE CASE OF OFF-FARM EMPLOYMENT IN IOWA 11

INTRODUCTION 12

ENTERPRISE CHOICE AS A PREDICTOR OF PART-TIME FARMING 15

Definition of a Part-Time Farmer 15

Reasons for Part-Time Farming 15

Compatibility of Part-Time Farming with Alternative Enterprises 17

PART-TIME FARMING IN IOWA 19

Description of Census Data Set 20

Results of the Regression Analysis 23

Implications of the Model 26

A NORMATIVE MODEL FOR FARM/OFF-FARM EMPLOYMENT CHOICES 30

General Assumptions of the Model 31

RESULTS OF THE NORMATIVE MODEL 41

Sensitivity Analysis 44

Summary of the Normative Results 55

THE NORMATIVE MODEL WITH RISK 58

Adapting the Certainty LP Model 58

Page

Results from the Target MOTAD Model 60

SUMMARY OF THE IMPLICATIONS DRAWN FROM THE NORMATIVE ANALYSIS 65

COMPARISON OF THE RESULTS FROM THE POSITIVE AND NORMATIVE MODELS 67

BIBLIOGRAPHY 71

APPENDIX 73

SECTION II. A MULTIPERIOD EVALUATION OF ALTERNATIVE STRATEGIES FOR IOWA BEEF COW-CALF PRODUCERS 75

INTRODUCTION 76

Objectives of the Study 80

REVIEW OF MULTIPERIOD RISK MODELS 82

ANALYTICAL MODEL 88

EMPIRICAL MODEL 90

Background on Retained Ownership Strategies 90

The Representative Farm Model 91

Price Data and Marketing Activities 98

BUDGET ANALYSIS 105

RESULTS OF THE MULTIPERIOD TARGET MOTAD MODEL 108

The Base Case 108

Implications of Results from the Base Case 114

Sensitivity Analysis 114

Implications from the Sensitivity Analysis 124

The Model with Perfect Information 126

SUMMARY AND CONCLUSIONS 129

BIBLIOGRAPHY 131

	Page
APPENDIX A	135
Introduction	135
APPENDIX B	163
Survey Information on Custom Feeding Alternatives	163
APPENDIX C	166
A Model for Generating Optimal or Near-Optimal Rations for Beef Cattle	166
APPENDIX D	175
Agricultural Commodity Options	175
GENERAL SUMMARY	178
GENERAL BIBLIOGRAPHY	180
ACKNOWLEDGMENTS	182

LIST OF TABLES

Page

SECTION I.

Table 1. Variable definitions 22

Table 2. Results of the regression analysis, models A and B 24

Table 3. Results of the regression analysis, models C and D 26

Table 4. Summary of the positive analysis: type and strength of the relationships of livestock enterprises to the prevalence of part-time farming 28

Table 5. List and definition of selected variables in the normative model 38

Table 6. Optimal solutions to the normative model for the base case and for selected sensitivity analysis cases 42

Table 7. Trade-offs between risk and mean income with associated enterprise combinations for target MOTAD at selected targets and negative deviations 61

SECTION II.

Table 1. Comparison of net returns from projected budgets of production and selling activities 106

Table 2. Level of investment and production activities for the base case 109

Table 3. Level of buying and selling activities associated with the base case 111

Table 4. List and definition of variables 115

Table 5. Comparison of the activity levels from the base case and selected sensitivity analysis cases 117

LIST OF TABLES FOR APPENDICES

		Page
Table A.1.	Budget and technical coefficients for cow-calf enterprise based on 1982 to 1988 averages	136
Table A.2.	Budget and technical coefficients for calves on a high roughage wintering program based on 1982 to 1988 averages	138
Table A.3.	Budget and technical coefficients for calves on a high grain backgrounding program based on 1982 to 1988 averages	140
Table A.4.	Budget and technical coefficients for grazing stocker cattle on summer pasture based on 1982 to 1988 averages	141
Table A.5.	Budget and technical coefficients for feedlot finishing of backgrounded calves based on 1982 to 1988 averages	142
Table A.6.	Budget and technical coefficients for feedlot finishing of summer pastured cattle based on 1982 to 1988 averages	143
Table A.7.	Budget and technical coefficients for custom feeding weaned calves based on 1982 to 1988 averages	144
Table A.8.	Budget and technical coefficients for custom feeding wintered calves based on 1982 to 1988 averages	145
Table A.9.	Budget and technical coefficients for custom feeding backgrounded calves based on 1982 to 1988 averages	146
Table A.10.	Budget and technical coefficients for custom feeding cattle coming off summer pasture based on 1982 to 1988 averages	147
Table A.11.	Monthly Iowa cash crop prices	148
Table A.12.	Cattle price series for selected months from 1982 to 1988 in real prices in 1988 dollars	150

Page

Table A.13. Futures contract hedges (all values are real prices in 1988 dollars) 154

Table A.14. Put option hedging strategies 157

Table A.15. Low cost cattle feeding facilities investment renovating or remodeling existing farm buildings 160

Table C.1. Feed ingredient available for ration and prices 171

Table C.2. Comparison of two rations and rates of gain for a 510 pound steer 172

Table C.3. Optimal return ration for a 510 lb medium-frame steer 173

Table C.4. Comparison of diets for a steer in the backgrounding program 174

LIST OF FIGURES

Page

Figure 1. Flow chart showing the timing of and interrelationships between the on-farm production activities over a three year planning horizon 97

GENERAL INTRODUCTION

In recent decades, American agriculture has been characterized by dramatic changes in its structure. These changes have contributed to the increasing levels of uncertainty and financial stress faced by farm families and have made risk management and strategic planning even more important.

One of the most striking structural changes has been the rapid increase in the prominence of part-time farming. According to the USDA (USDA, 1987), the dependence on "off-farm" income nationwide has increased from 39 percent of total income in 1960 to a high of more than 68 percent in 1983. During the period 1983 to 1987, off-farm income averaged about 60.5 percent of total income for the U.S. and 52 percent in Iowa. The earnings from off-farm employment have become essential to supplement family income for many small- and medium-sized family farms. These facts suggest that other opportunities or alternatives for the farm family's labor resources, outside the traditional farming operation, affect the resource allocation decisions of the farm family.

The fundamental problem of the theory of the firm is to determine the allocation of resources which will maximize the firm's profits. Similarly, farm families must also decide how to allocate resources among several alternative crop and livestock enterprises and off-farm employment activities which will maximize net family income. If the farm family has other goals and objectives, besides the maximization of net family income, such as stable annual income, the problem becomes one of maximizing utility. With the presence of off-farm employment opportunities and uncertain farm prices and production, maximizing farm profits may not necessarily maximize the family's expected utility. In a world filled with uncertainty[1], the risk preferences of the family become an important consideration which should be accounted for in a planning model.

Once a particular plan of action is selected and implemented, the farmer loses a certain degree of flexibility. In most cases, farm enterprises require some fixed investment in equipment or facilities, and there may also be other start-up costs as well. Future reallocations of resources from one enterprise into another may be costly because assets are fixed and not easily converted into other uses or cash. In this context, the initial enterprise selection decisions are of a long-run strategic planning nature because of asset fixity in the short run.

Explanation of Thesis/Dissertation Format

This thesis consists of two articles in applied farm management utilizing a farm planning model and a linear risk programming technique. Both articles involve farm planning problems addressing

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[1]This thesis makes no distinction between the terms risk and uncertainty and will use them interchangeably to describe any situation where future events are not known with certainty whether or not subjective probabilities can be placed on the occurrence of specific future events.

selection of optimal farm enterprise combinations under uncertainty for representative farms in southern Iowa.

The first article studies the compatibility of off-farm employment with crop and livestock enterprises, and then incorporates risk considerations into the farm planning and decision making processes of part-time farmers or those farmers presented with potential off-farm employment opportunities. The risk programming technique called "target MOTAD" (Tauer, 1983) is used to demonstrate the effects of risk and off-farm employment on decision making for a representative south central Iowa farm.

The second article explores retained ownership decisions by beef cow-calf producers in southern Iowa using a partial farm optimization model approach which focuses on the relationships and interactions among the cow-calf, cattle feeding, and crop production enterprises. Again, risk is explicitly accounted for within this model. The intent of this article is to analyze different production and marketing strategies which will help beef cow-calf producers improve their relative profitability.

The two articles are related, yet independent, bodies of work--each with their own references and appendixes. An overall summary and discussion of the entire thesis is included following Section Two.

Review of Risk Programming Literature

A much used tool for extending the theory of the firm to agriculture has been linear programming. In the traditional linear programming formulation, data which are entered in the objective function are treated as if they are occurring with perfect certainty. Although this technique has provided much useful information about resource allocation, the results have not always been consistent with observed patterns.

Freund (1956) showed that linear programming under certainty produces solutions that are frequently rejected because they imply a more aggressive production plan than most farmers are willing to accept. Freund set the problem of risk into a quadratic framework by assuming that the farmer had a negative exponential utility function and that the distribution of profits was normal. This gives an expected utility function which is a linear function of the mean and variance of returns. He selected a level for the farmers' risk aversion parameter and optimized by maximizing the net revenues minus the risk cost subject to the resource constraints. The model in his mathematical notation is as follows:

$$\text{Max } E[U] = s'x - a/2*x'Gx$$

such that

$$Tx <= v$$

and $x >= 0$,

where s is a vector of net revenues, x is a vector of production activities, a is the risk aversion parameter, G is the variance-covariance matrix of net revenues for each production activity, T is the matrix of scarce resource requirements for each production activity, and v is the vector of scarce resources. He found that with the introduction of risk into the programming model the solutions more accurately reflected actual farmer behavior.

Lin, Dean, and Moore (1974, p. 497) claim that most linear programming studies which have used profit maximization as a goal have led to results which do not conform to existing patterns. The observation of farmers' actual behavior suggests that uncertainty or risk needs to be incorporated into the models. The conclusion that incorporating risk into farm-planning models is desirable has a sound theoretical basis, however, the best procedure for doing this is still subject to debate.

The maximization of von Neumann-Morgenstern (von Neumann and Morgenstern, 1947) expected utility has become a widely used goal in studies of risk. The form of expected utility function reflects the risk preferences of the farmer. However, the determination of farmers' utility functions is not always practical, so most risk programming models assume a functional form that is computationally convenient. One method is to assume that an individual associates risk with the variance of return so that the expected utility from income decreases as the variance of income rises which leads to a mean-variance analysis. There are two circumstances under which mean-variance (E-V) analysis is consistent with expected utility theory (Tobin, 1958). One is when the distribution functions for all risky activities are normal and thus can be completely described by their means and variances. An additional condition of negative exponential utility preferences is necessary to obtain a linear functional form of the mean and variances. The second case is when the form of the utility function is quadratic.

Markowitz's (1959) work in portfolio theory first introduced the idea of deriving an expected profit-variance (E-V) frontier from quadratic programming models. E-V analysis bases the selection of risky prospects on the means and variances of their probability distribution of returns. The E-V frontier defines a set of risk efficient solutions (i.e., minimum variance for a given mean return). The decision makers then choose among the alternative solutions from the E-V efficient set based on their risk preferences.

An alternative risk efficiency criterion is stochastic dominance (Anderson et al., 1977). In general, stochastic dominance is a pair-wise comparison of cumulative probability distributions for different risky alternatives. If one risky alternative is dominated by another, then the dominated alternative can be eliminated from the efficient set. Second degree stochastic dominance (SSD) holds for all decision makers whose utility functions are concave and as such are risk averse. Under SSD, an alternative with the cumulative distribution function F(y) is preferred to a second alternative with the cumulative distribution function G(y) if F(y) <= G(y) for all possible values of y and if the inequality is strict for some value of y. The SSD efficient set is identical to the E-V efficient set when the outcome distributions are normal.

Hazell (1971) outlined a linear alternative to quadratic programming which minimizes total absolute deviations around the mean level of income to derive risk efficient expected income-absolute deviation (E-A) frontiers. The minimization of total absolute deviations, or MOTAD, was compared and contrasted with quadratic programming and expected income-variance (E-V) analysis. MOTAD was also compared with the expected income-semivariance (E-S) method of risk incorporation. Hazell found similar solutions when using either MOTAD or quadratic programming. In fact, the MOTAD approach may be preferred to the mean-variance approach if the return distributions are skewed.

Johnson and Boehlje (1981, 1982) showed that in many cases when expected utility problems can be transformed into E-V problems, they can also be transformed into MOTAD problems. They conclude that E-V problems and E-A problems are theoretically equivalent under more general conditions than normality. Thus, the choice between quadratic programming or MOTAD depends on the distribution of the data.

Tauer (1983) and Watts et al. (1984) nearly simultaneously arrived at a new method of including risk in the linear programming model. They presumed that most farmers do not base their estimation of the risk associated with a particular crop on the mean and variance but rather on some target level of income and the negative deviation from that fixed point. "Target MOTAD" maximizes mean income subject to a limit on the total negative deviations measured from a fixed target rather than from the mean. The implied utility function is linear:

$$U(z) = a + bz + c(z - h) \quad \text{if } z <= h,$$

$$U(z) = a + bz \qquad \text{if } z >= h$$

where a, b, and c are constants > 0, h is the fixed reference point of target, and z is the random variable. This function is increasing and concave over z.

The mathematical formulation for the target MOTAD model is as follows:

$$\text{Max } E(Z) = \Sigma\, c_j x_j \qquad j = 1,2,\ldots,n$$

such that $\qquad k = 1,2,\ldots,p,$

$$\Sigma_j a_{ij} x_j \leq b_i \qquad i = 1,2,\ldots,m,$$

$$T - \Sigma_j c_{rj} x_j - q_r \leq 0 \qquad r = 1,2,\ldots,s,$$

$$\Sigma_r p_r q_r <= \mathcal{L} \qquad \mathcal{L} = M \rightarrow 0, \text{ and}$$

$$x_j >= 0 \;,\; q_r >= 0$$

where E(Z) is the expected income of the solution, $\bar{c}_j$ is the expected return of activity j, T is the target level of income, c_{rj} is the return of j^{th} activity for the r^{th} observation, p_r is the probability observation r will occur, and $\mathcal{L}$ is the absolute value of expected negative deviations from the target income level. $\mathcal{L}$ is a constant which is parameterized from 0 to M, with M being a large number, to derive the E-A efficient set of target MOTAD solutions for each given level of target income.

Target MOTAD has the advantage of selecting solutions which are members of the second-degree stochastic dominance (SSD) efficient set, whereas ordinary MOTAD does not necessarily have this property. Tauer comments that since no one has yet developed a stochastic dominance algorithm to select dominant plans from individual activities, plans must first be generated by some other selection process and then tested for stochastic dominance. Thus, target MOTAD is one way to generate a partial set of SSD efficient solutions.

While the target MOTAD approach is consistent with the expected utility hypothesis, when certain assumptions are satisfied, it also has a broader theoretical appeal. This is because the minimization of the total absolute negative deviations from a target level of income captures some of the same ideas and reasoning of the safety-first approach of decision making. A safety-first criterion may be more appropriate for modeling the behavior of limited resource farmers or small farms which are most frequently part-time farming operations as well.

In summary, most risk programming techniques are attempts to better represent decision making in the real world. The appropriate or "best" measure of risk ultimately depends on the underlying (and in most cases unknown) utility function of the decision maker. Two approaches have been used to incorporate risk into nonsequential mathematical programming models--the first being quadratic programming methods and the second being linear measures of risk such as the MOTAD and target MOTAD risk programming models.

Quadratic programming considers only the mean and variance (and covariances) of activity returns to be important. However, if the activity returns are not normally distributed this approach implicitly rules out consideration of higher moments of the probability distribution of returns such as skewness and kurtosis. In contrast, the MOTAD and target MOTAD models make no assumptions about the distribution of stochastic variables and focuses on the negative deviations from its mean or a total income target level.

In many situations there are practical advantages to using linear risk programming methods. First, large linear models may be computationally easier to solve than quadratic programming models and, therefore, one can build larger, more complex linear models than quadratic programming models. However, recent advances in nonlinear programming methods have decreased or overcome this advantage for some applications (McCarl and Onal, 1989). Secondly, linear models will more easily accommodate variables which must be constrained to either 0 or 1, or integer values. Perry et al. (1989) have recently included integer decision variables in a nonlinear programming model through the use of a Benders' decomposition approach that allows the problem to be decomposed into two easier-to-solve problems.

SECTION I. POSITIVE ANALYSIS AND NORMATIVE PROBLEMS: THE CASE OF OFF-FARM EMPLOYMENT IN IOWA

INTRODUCTION

Economists often distinguish between positive economic analysis which is concerned with understanding and predicting economic behavior and normative analysis which is concerned with what "ought" to be. Researchers interested in the use of optimization models for policy analysis often use a third type of analysis called conditional normative or conditionally predictive analysis. This method of analysis predicts what economic behavior would be if decision makers possessed certain technologies and followed particular decision strategies. While many normative studies in farm management are based on representative farms, the implied optimal choices are often applied to the entire strata of farms. "Optimal" predicted acreage responses may often differ from those observed in the real world (Wipf and Bawden, 1969). At the individual firm level, "recommended" enterprise choices may be significantly different than current practices. The discrepancy between actual choices and those predicted by normative models may be due to several factors. Among these factors are improper specifications of technology or decision maker preferences, improper attention to constraints faced by decision makers, or models that do not reflect the actual choice set of decision makers. For example, engineering production functions may represent production levels not typically attained in practice. Recently, Ray (1985) has proposed the use of regression analysis to estimate input coefficients for linear programming models in order to reduce this problem. Such a combining of positive information and actual choices with normative methods of analysis may be fruitful in addressing other problems as well. Could positive analysis of decision maker choices in one environment be used to improve or refine normative estimates of decision maker choices in alternative environments? Can the empirical curiosities discovered by positive methods be explained by analyzing normative models and vice versa? Can positive studies provide a benchmark against which to calibrate or judge normative results? The use of positive analysis in the development of normative models seems a fruitful endeavor worthy of pursuit (Shumway and Chang, 1977).

Given this line of reasoning, this paper analyzes off-farm employment choices for Iowa farmers in both a positive and normative framework. Positive analysis provides information on those enterprises compatible with off-farm employment and suggests several hypotheses about the types of enterprises that will be chosen in normative models. A normative programming model representing off-farm employment opportunities uses this information both to construct the model and judge its relationship to real-world decisions. This model in turn suggests further positive hypotheses to be investigated. This intertwining of positive and normative analysis--positive suggesting modifications to normative, normative presenting new hypotheses to test--allows clearer and more precise analysis of the problem than available through singular methods.

This paper then is about methods, the combining of positive and normative analysis, but it is primarily about off-farm employment. The problem illustrates the methods and the methods, hopefully, shed light on the problem. The first section of the paper describes a positive analysis of part-time farming in Iowa. The implications of this analysis are used in constructing a mixed integer risk programming model of a representative Iowa farm household. The results of the programming model are then compared to the positive observations, differences noted and new hypotheses proposed. The paper ends sometime before the convergence of this process.

ENTERPRISE CHOICE AS A PREDICTOR OF PART-TIME FARMING

Definition of a Part-Time Farmer

In order to explain off-farm employment and part-time farming, some possible definitions are discussed. In the broadest sense, the range of part-time farming operations lies between the case where all of the family's labor resources are employed in farming to the case where all labor resources are employed off the farm. A general definition of a part-time farming operation is a farm operation where a significant amount of any family member's labor resources is devoted to off-farm employment.

The practicality of using census data limits the positive analysis described in this paper to a narrower functional definition. A farm operation is defined to be part-time if the principal farm operator worked 100 days or more off the farm during the year. Although this definition of part-time farming only considers the principal farm operator and arbitrarily uses 100 days of off-farm work as the cut-off point for part-time farming, it accounts for the majority of part-time farming operations in Iowa.

Reasons for Part-Time Farming

Many theories have been developed to explain the existence of part-time farming operations, none of which are completely satisfactory. One theory is that part-time farming operations are a transitive form of adaptation for those families who are either entering or leaving farming. However, many part-time farming operations are a stable component of the agricultural structure.

One reason for holding an off-farm job is to reduce overall risk. The off-farm job provides a certain "safety net" level of income for the family if the farming operation is not profitable. Without off-farm employment opportunities the farmer may instead try to reduce or spread risks by diversifying the enterprise mix of the farming operation.

In general, there is an inverse relationship between the size of the farming operation and off-farm income such that small farmers have the highest level of off-farm income (USDA, Office of Rural Development Policy, 1984). Smaller-than-average sized farms which are more likely to be part-time farming operations may be either specialized or diversified. Part-time farmers may specialize or limit themselves to a few enterprises because of resource or managerial constraints. For example, some part-time farmers have moved into specialty enterprises such as apple orchards, consumer harvested berry patches, or organic vegetable operations (Cochrane, 1987). Conversely, other part-time farmers may want to spread risks among several enterprises and diversify because their small scale of production does not allow them to capture any economies of scale in a single enterprise.

Resource limitations are another reason why part-time farming has developed in the past. For example, many young farmers that had inadequate capital resources started farming on a small scale part-time before becoming established full-time farmers. In addition, the off-farm employment of one spouse may enhance the farmer's ability to obtain credit. Farm size may be temporarily constrained by the inability to buy or rent additional farmland.

Part-time farming also offers flexible supplemental employment for someone who wants to work more than 40 hours a week. Also, for those employed full-time off the farm, the farm operation may be considered a leisure activity rather than an employment choice.

In many types of farming operations the farmer's labor is under-utilized during certain times of the year. Thus, for example, a cash grain farmer may seek seasonal off-farm employment in the winter to utilize excess labor resources.

Compatibility of Part-Time Farming with Alternative Enterprises

There is reason to expect part-time farmers to select enterprises that are less labor intensive or that have compatibility in the scheduling of labor requirements. For example, as mentioned above, cash grain farmers have slack labor demands during the winter months which is conducive to seasonal off-farm employment. Dairy farming on the other hand is a rather labor intensive enterprise which requires a certain number of hours of labor every day year round. A dairy enterprise also requires a high capital investment in equipment and facilities. Thus, dairying appears to be less compatible with part-time farming. Livestock feeding enterprises such as hog feeding and cattle feeding have relatively low labor requirements and may require less managerial skill than breeding operations. These livestock feeding enterprises also have low capital requirements for equipment, facilities and herd inventory which may make them more attractive to part-time farmers than breeding enterprises.

PART-TIME FARMING IN IOWA

Part-time farmers make up a significant proportion of all farmers in the state of Iowa. In 1982, the proportion of farmers working 100 days or more off the farm during the year was 27.8 percent and in 1978 the proportion was 26.3 percent (U.S. Bureau of the Census, 1984). The majority of these part-time farmers worked more than 200 days off the farm during the year.

Simple empirical analysis is one way to get a generalized view of part-time farming characteristics in Iowa. The positive model presented here utilizes a multiple regression analysis of aggregate county level census data to determine which farm enterprises are associated with part-time farming. The dependent variable for this regression analysis is the proportion of part-time farmers in a county and the independent variables are the proportion of farms in the county with a given livestock enterprise at any level of production and selected control variables.

In Iowa, certain common crop enterprises are basic to most farms, so measuring the proportion of farms growing corn, soybeans, oats, or hay and including them as independent variables are not considered to be important discriminating factors in this analysis. Farms producing specialty crops (i.e., vegetables, sweet corn, or melons; fruits, nuts or berries; nursery and greenhouse products; or other crops) make up a very small proportion of the total number of farms across the state and are insignificant in the county level census data.

In order to determine the effects of enterprise compatibility, the analysis controls for differences between counties due to other factors which may also influence part-time farming such as the availability of off-farm employment, urbanization of the county, relative location of major employment centers, relative location of smaller rural employment centers, and farm size. Various livestock enterprise variables were added to the controlled model to test their relative significance with the prevalence of part-time farming. The relative importance of a given livestock enterprise in a particular county is measured by the percentage of farms in the county engaged in that enterprise.

We hypothesize that if a livestock enterprise is compatible with part-time farming then it will have a significant positive coefficient in the regression model. Livestock enterprises that are not compatible are expected to have a significant negative relationship with the dependent variable.

Description of Census Data Set

Data from the 1982 Census of Agriculture (U.S. Bureau of the Census, 1984) for Iowa at the county level were used to define the dependent variable and several independent variables for the regression analysis. The dependent variable under study is the percentage of part-time farmers in a county. Part-time farmers are defined as those farm operators who reported working 100 days or more off the farm.

Demographic information such as the total 1980 population of each county and the number of persons employed in farming occupations and nonfarming occupations about each county was obtained from the 1980 Census of Population (U.S. Department of Commerce, 1981). This information was used to create the variable, percentage of persons employed in nonfarm occupations (%NFE), which is used as a proxy for the availability of off-farm employment opportunities for the farmers in a given county. However, this variable may bias results because it counts part-time farmers whose primary occupation is other than farming and so counties that have a high prevalence of part-time farming tend to have a higher percentage of nonfarm employment. Other variables tested as proxies for the availability of off-farm employment opportunities included the population density of the county, the distance from the county seat to the closest city greater than 10,000 in population, and a set of city size dummy variables for each county. These variables measure the rural or urban characteristics of a county indicating the amount of nonfarm employment in the county and, thus, its potential for off-farm jobs.

An enterprise diversity (E.D.) measure was calculated by using the following formula (Albrecht and Murdock, 1984, p. 401):

$$E.D. = NC \; [\; 1 - \{(\Sigma|X - X|)/2\}/\; \Sigma X \;]$$

where X is the number of farms in each standard industrial code (SIC) category and NC is the number of SIC categories used. The hypothesis is that counties with greater enterprise diversity will show a higher prevalence of part-time farming.

The definitions of the control variables used in the regression analysis and the independent variables defined to determine the level of a given farm enterprise in a county are listed in Table 1.

Table 1. Variable definitions

%NFE	=	persons employed in nonfarm occupations divided by the total number of persons employed in the county.
CITYSIZE1	=	a dummy variable that is set equal to one if the county has a city with a population of 20,000 to 40,000; zero if otherwise.
CITYSIZE2	=	a dummy variable that is set equal to one if the county has a city or metropolitan area with a population of greater than 40,000; zero if otherwise.
DISTANCE	=	the distance measured in miles from the center of the county to the nearest city of 10,000 or greater population. If the county has a city larger than 10,000 the distance is set to zero.
FARMSIZE	=	the average size of farm in acres for a county.
$EQUIP	=	the total value of farm machinery and equipment divided by the total value of gross farm sales in the county.
E.D.	=	a measure of enterprise diversity in the county.
DAIRY	=	the proportion of all farms which sold dairy products in 1982.
B. COWS	=	the proportion of farms which had beef cows in inventory in 1982.
CATTLE	=	the proportion of farms fattening cattle for slaughter using grain concentrates in 1982.
HORSES	=	the proportion of farms that sold horses during 1982.

Table 1. Continued

HOG FEED	=	the proportion of farms that purchased feeder pigs and fed them for slaughter (excludes farrow-to-finish operations) in 1982.
FARROWING	=	the proportion of farms farrowing litters of pigs during 1982.
SHEEP	=	the proportion of farms with sheep on inventory in 1982.

Results of the Regression Analysis

The basic regression models shown in Table 2 use the percentage of persons employed in nonfarm occupations (%NFE) and the enterprise diversity (E.D.) measure as control variables. These two control variables alone explain 52.6 percent of the variation in the prevalence of part-time farming among counties. The inclusion of the control variables FARMSIZE and $EQUIP in regression model A fix the "plant size" of the farming operation relative to other farm operations in other counties. Model B in Table 2 does not include the variables FARMSIZE and $EQUIP thus allowing the farm production capacity to be variable. The control variables used in models A and B had the expected signs and were all significant except for $EQUIP which had a very low t-ratio. The livestock enterprise variables DAIRY, B. COWS, HORSES, FARROWING, and CATTLE were found to be statistically significant at the .05 level in both models A and B. Similar results were also obtained when the county's population density (defined as 1980 population per square mile) was used instead of %NFE.

Table 2. Results of the regression analysis, models A and B

	Model A R^2= .9072			Model B R^2= .8769		
	Estimated			Estimated		
Variable	Coeff.	Std. error	t-ratio	Coeff.	Std. error	t-ratio
%NFE	0.3011	0.0648	4.65***	0.4896	0.0578	8.47***
FARMSIZE	-0.0595	0.0125	-4.78***			
$EQUIP	2.0591	3.2704	0.63			
E.D.	6.7815	1.4906	4.55***	11.3887	1.3283	8.57***
B. COWS	0.1647	0.0242	6.81***	0.1638	0.0265	6.19***
DAIRY	-0.3585	0.0648	-5.53***	-0.4139	0.0708	-5.84***
FARROWING	-0.1741	0.0562	-3.10***	-0.0924	0.0554	-1.67*
HOG FEED	-0.0730	0.1790	-0.41	0.2519	0.1756	1.44
HORSES	1.0716	0.3527	3.04***	0.8301	0.3983	2.08**
CATTLE	-0.1261	0.0654	-1.93*	-0.1483	0.0708	-2.09**
SHEEP	0.0607	0.1051	0.58	0.2510	0.1122	2.24**

*Significant at 0.05 level.

**Significant at 0.025 level.

***Significant at 0.005 level.

The results show that beef cow-calf enterprises and raising horses for sale are positively related with the prevalence of part-time farming whereas dairying, hog farrowing, and feeding cattle have an inverse relationship. The regression coefficient for the variable SHEEP is not significantly different from zero in model A, however, in model B, its coefficient is significant and in both cases the sign is positive as was expected. The variable HOG FEED (hog feeding) is not significantly different from zero in either model A or B. However, the sign of the regression coefficient for HOG FEED is negative in model A where production capacity is controlled for, but then is positive in model B where production capacity is variable.

The regression models shown in Table 3 use a different set of control variables as proxies to account for the availability of off-farm employment opportunities. The variable %NFE is replaced with the variables CITYSIZE1, CITYSIZE2, and DISTANCE which are now used to control for the presence or absence of off-farm job opportunities. All other control variables used in models C and D are the same as before. Model C explains 89.04 percent of the variation in the dependent variable, and the livestock variables B.COWS, DAIRY, FARROWING, HOG FEED, and HORSES were found to be significant at the .005 level. The other livestock variables, CATTLE and SHEEP, have low t-ratios which are not significant. In model D, the livestock variable HOG FEED becomes nonsignificant although its estimated regression coefficient remains negatively signed. The regression coefficient for CATTLE is not significantly different from zero in either model C or model D.

The results for the remaining livestock variables, B.COWS, DAIRY, FARROWING, and HORSES, are comparable to those obtained from the regression models in Table 2.

Table 3. Results of the regression analysis, models C and D

	Model A R^2= .8904 Estimated			Model B R^2= .8189 Estimated		
Variable	Coeff.	Std. error	t-ratio	Coeff.	Std. error	t-ratio
CITYSIZE1	1.3934	1.2583	1.11	2.9095	1.5746	1.85*
CITYSIZE2	1.5962	1.1902	1.34	3.2042	1.4754	2.17**
DISTANCE	-0.0184	0.0198	-0.93	-0.0551	0.0243	-2.27**
FARMSIZE	-0.0856	0.0117	-7.32***			
$EQUIP	-1.2890	3.5491	-0.36			
E.D.	5.8296	1.6378	3.56***	13.3090	1.6334	8.15***
B. COWS	0.1535	0.0297	5.17***	0.1291	0.0354	3.65***
DAIRY	-0.3777	0.0743	-5.08***	-0.5223	0.0883	-5.92***
FARROWING	-0.2517	0.0583	-4.32***	-0.1447	0.0677	-2.14**
HOG FEED	-0.4573	0.1636	-2.80***	-0.2072	0.1979	-1.05
HORSES	1.2513	0.3886	3.22***	1.0127	0.4911	2.06**
CATTLE	-0.0829	0.0716	-1.16	-0.0185	0.0837	-0.22
SHEEP	-0.0088	0.1161	-0.08	0.1920	0.1413	1.36

*Significant at 0.05 level.

**Significant at 0.025 level.

***Significant at 0.005 level.

Implications of the Model

The results from the regression models do indeed substantiate some of the initial hypotheses about the compatibility of certain farm enterprises with part-time farming. The results are summarized in Table 4. Dairying and farrowing sows, which are labor and capital intensive enterprises, were negatively related to part-time farming as expected. Beef cow enterprises and raising horses for sale were found to be positively related. Although raising horses can be an economically viable enterprise in some situations, it is probably more of a "hobby" enterprise for many part-time farmers.

The analysis provides inconclusive results about the relationship of such enterprises as hog feeding and sheep and cattle feeding to part-time farming. The cattle feeding enterprise had a significant negative correlation with part-time farming in models A and B which was just the opposite of what was expected. In retrospect, this result may be explained by area differences. Cattle feeding is concentrated in northwest and west central Iowa where there is less part-time farming on average. Therefore, our results may be unduly biased against a positive relationship between part-time farming and cattle feeding.

One problem with using aggregate county-level census data is that there is nothing that identifies or separates the individual part-time farming operations to link them to specific crop and livestock production activities. Thus, the positive analysis only shows the general tendency of a county with a high amount of part-time farming to be associated with different types of livestock enterprises indirectly measuring enterprise compatibility to part-time farming. The results generated by this positive analysis can be used to help construct a normative model by ruling out certain enterprises and constructing hypotheses to be tested.

Table 4. Summary of the positive analysis: type and strength of the relationships of livestock enterprises to the prevalence of part-time farming

	Direct	Inverse
BEEF COWS	+++	
DAIRY		---
SOW FARROWING		--
HOG FEEDING		-
HORSES	++	
CATTLE FEEDING		-
SHEEP	+	

Specifically, it will be assumed that dairy farming is not a relevant enterprise choice for most part-time farmers and it can be excluded from the normative model. Furthermore, the following hypotheses are made:

1) Although beef cow-calf enterprises are very typical, in many areas of Iowa they are rarely selected as an optimal enterprise choice by normative methods (Miller et al., 1978, Musser et al., 1975). However, since the positive analysis seems to imply that cow-calf enterprises are associated with part-time farming, we hypothesize that a normative model which considers off-farm employment (i.e., part-time farming) will frequently select beef cow-calf enterprises as a production activity.

2) Since sow farrowing enterprises require more labor and capital than most part-time farmers are able to commit to operate on an efficient scale, we hypothesize that sow farrowing will be less likely to be chosen by part-time farmers.

3) Hog feeding may be important in part-time farming operations depending on each farmer's specific circumstances. If the farmer has unused or under-utilized livestock facilities which can be adapted to feeding hogs, then this enterprise is a relevant choice. If facilities are limited or already in use by other livestock enterprises, then hog feeding may be a less attractive alternative. We hypothesize that the selection of the hog feeding enterprise in the normative model will depend on the availability of facilities relative to other uses.

A NORMATIVE MODEL FOR FARM/OFF-FARM EMPLOYMENT CHOICES

Conditionally normative models try to determine optimal resource allocations for given situations. By applying the information gleaned from the positive analysis, more realistic and specific normative models can be constructed. A mixed integer linear programming (MILP) model is utilized to study the farm and off-farm employment decisions of a farm family with the objective of maximizing net family income (Murty, 1976). The model was solved on an IBM-compatible personal computer using the LINDO programming software (Schrage, 1986).

The MILP model is significantly more realistic than earlier LP models in modeling the reality of labor allocation decisions and off-farm employment opportunities. The model includes several different crop rotations and livestock enterprise choices which are most likely to be compatible with part-time farming as indicated by the positive analysis. Another feature is the inclusion of labor substitution ratios that can differ between the principal farm operator and other family members. The labor constraints are divided by individual, month, and time of day to provide a detailed breakdown of labor usage. The model also includes constraints limiting the total annual hours an individual can work. This allows a certain amount of flexibility in the monthly labor constraints so that more hours per month can be worked during periods of high seasonal demand as long as the limit on total annual hours is not exceeded.

Another feature of the model which adds more realism is the use of zero/one integer variables to model the off-farm job activities and fixed costs for the livestock enterprises. Finally, price and crop yield uncertainty are incorporated into a modified version of the basic LP model to determine the effects of risk averse behavior.

General Assumptions of the Model

The data used in constructing this model focuses on a representative medium-sized farm in south central Iowa. South central Iowa has a higher proportion of part-time farming relative to other areas in Iowa and is predominantly rural with smaller cities and towns providing off-farm employment opportunities. It is also an area with a substantial amount of "limited resource" farming and so off-farm employment for these farmers may be necessary for their survival.

The farm resources available are 300 acres of tillable land that is equally divided among three classes of land. The three land classes are based on an average corn suitability rating[1] (CSR) index of 70, 50, and 30, respectively. Class 3 land (CSR=30) is presently in pasture but can be row cropped on a limited basis. Due to soil conservation considerations, only a corn-corn-corn-oats-meadow-meadow[2]

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[1]"Corn suitability rating is an index procedure developed in Iowa to rate each different kind of soil for its potential row-crop productivity" (Miller, 1985). The index ranges from 0 to 100 and is based on soil properties, average weather, and the inherent potential of each kind of soil for corn production.

[2]The meadow crop is an alfalfa-bromegrass mixture which is harvested as hay.

(CCCOMM) crop rotation or a corn-corn-oats-meadow-meadow (CCOMM) rotation is allowed on class 3 land. In addition to the owned land, the farmer can cash rent up to 300 acres of crop land which contains equal proportions of class 1 and class 2 land. The crop yields used in the model are averages based on the productivity rating for the classes of land defined for south central Iowa. The farm is also assumed to have an adequate line of machinery for crop production.

The representative farm's production costs are assumed to be for average management in the base year of 1986. The livestock prices used in the model are based on a seven-year average from 1980 to 1986. Grain prices were based on a five-year average (1982-1986) of south central Iowa cash prices. All price data were converted to a 1986 basis using the implicit GNP price deflator to adjust the historical average gross returns from the farm activities to 1986 production costs.

The timing of grain sales and purchases is preset by the model. These restrictions to the marketing plans for crops are made to keep the model from becoming too complex. However, there is no reason to believe that a marketing plan different than the one assumed would significantly affect the results as to part-time farming since monthly borrowing activities are unconstrained.

Enterprise choices

The model farm can produce five different crops (corn, soy-beans, oats, hay, and pasture grass) in 12 different crop rotations. The production of soybeans is limited to class 1 and class 2 land because of soil conservation considerations. The livestock enterprises included in the model are sow farrowing, hog feeding, beef cow-calf, cattle feeding, sheep, and feeding lambs. The following is a brief description of each livestock enterprise in the LP model.

1) There are three sow farrowing activities which are divided by the month of farrowing as follows: February and August, April and October, and June and December.

2) The hog feeding enterprise feeds a 50-lb feeder pig to market weight at 230 lbs. The model includes six separate hog feeding activities for feeding periods beginning in February, April, June, August, October, and December.

3) Three beef cow-calf enterprises which maintain a beef cow herd to calve in April are included in the model. The first activity sells the calves at weaning time (COWCALF). The second activity backgrounds and feeds the calves to be marketed as feeder cattle in February or March (COWCALF2). In the third activity, the calves are fed out and marketed for slaughter (COWCALF3).

4) Three cattle feeding enterprises purchase feeder cattle in the fall to be fed for slaughter. The FEEDSTR enterprise feeds steer calves weighing 450 lbs on a corn-hay ration to 1150 lbs. The FEEDHFR enterprise feeds heifer calves weighing 400 lbs to finish at 1000 lbs on a corn-hay ration also. The GRAZESTR enterprise purchases and winters steer calves weighing 450 lbs. These steers are put on

pasture in the summer and then placed in the feedlot on a corn-hay ration in the fall to be finished out by the following February.

5) The sheep production activity is a herd of at least 25 ewes which lamb in February. A 160 percent lamb crop is assumed with 20 percent used for replacements.

6) The lamb feeding enterprise purchases lambs weighing around 60 lbs in August or early September and feeds them to be marketed at 110 lbs in December.

Livestock facilities

The farm initially has 2800 square feet of available barn and shed space which can be used for housing sows, feeder pigs, feeder lambs, sheep, or feeder calves. Outside lot space is assumed to be nonconstraining. Calves can be fed in a separate outside lot and only require inside shed space during the winter months of November through February. These types of multiple use facilities are common on many part-time farms.

It is assumed that separate farrowing facilities with either a 16 or 32 crate capacity can be made available to the farm through the fixed cost activities. The farrowing facility will allow for farrowing three groups of sows twice a year. Space in the farrowing building is also provided for a pig nursery. The sows also need additional shed space during gestation and breeding periods and therefore will compete with the other livestock enterprises for housing and feedlot space.

Fixed costs

In certain situations it is not always acceptable to represent economic units as continuous variables. This may be particularly true for part-time farmers who are usually producing on much smaller scale than full-time farm operators. Many types of livestock facilities represent "lumpy" inputs of production which make it impractical to expand production capacity by only a small number of units. Thus, the fixed costs for a given set of livestock facilities are included as activities which "block" the fixed costs for arbitrarily, yet reasonably, sized units of livestock production facilities. These activities account for the additional fixed investment in equipment and facilities needed to produce a certain number of livestock.

The fixed cost activities are designated as zero/one integer variables which are linked to the production activities so that in order to produce a given number of units the model must incur the appropriate level of fixed costs for the corresponding production activity. Thus, the fixed cost activities act as step functions and there is an income penalty for under-utilizing the capacity of a given facility. The fixed cost activities for livestock represent only the investment in machinery, equipment, and facilities. The other fixed costs for insurance and interest on breeding stock are deducted directly from the production activities since they only depend on the per unit production level.

The fixed costs associated with the general farming operation are included in an overhead account activity; likewise, the family living expenses are also deducted by including another fixed cost activity. The fixed farm expenses include property taxes, insurance, building repairs, and fixed-interest payments. The opportunity cost of land is implicitly included in the model by the cash renting activities.

Labor endowments and constraints

The representative farm family includes the husband, the wife, and two children. All family members are willing and able to work on the farm as well as off the farm. The model tries to realistically reflect the farm family's labor employment decisions which adds complexity to the LP model. Monthly labor constraints are constructed to allow for flexibility during seasonal peaks of demand for labor. The monthly labor constraints are divided by person and time of day (i.e., either daytime or evenings). Additional constraints on annual hours worked by husband, wife, and their joint total are included to keep annual hours of labor within the preset bounds. In this way the model gives the family the flexibility to work more hours in the months when farm labor is critical but limits the total annual hours.

The model assumes that both the husband and wife are willing to work a maximum of 3000 hours per year. The two children can provide an additional 477 hours of labor per year. It is estimated that at least 1200 hours of either the husband's or wife's labor need to be allocated to household maintenance activities (Sharpe, 1986). Of this total, 600 hours are directly included in the model by household labor activities which assume that a specific amount of labor is required each month. The remaining 600 hours of household labor can be performed during any time period and so is accounted for by a constraint on the maximum number of hours the husband and wife can work jointly in one year (5400 hours).

The labor quality differences between farm family members is handled by putting farm enterprise labor requirements on a "principal operator equivalent hour" basis with corresponding labor substitution ratios. The potential differences between the husband's and wife's on-farm labor efficiencies for crop and livestock activities can be accounted for by varying the labor substitution ratios within the model. Initially, the labor provided by either the husband or wife is assumed to be equivalent for all farm activities. The children's farm labor is assumed to be less efficient than their parent's, requiring 1.2 hours to equal a principal operator equivalent hour.

Additional farm labor can be hired on a part-time seasonal basis in the months of April through November at a cost of $4.50 per hour. The hired farm labor is assumed to be less efficient than the farm operator's labor but of equivalent efficiency to the children's farm labor. The maximum amount of labor that can be hired in any given month is 160 hours, except for the summer months of June, July, and August when 200 hours per month can be hired because of the greater availability of students on summer vacation.

Off-farm job opportunities

The model presents the farm family with five hypothetical off-farm job activities which represent the kinds of potential employment opportunities available. The compensation for the off-farm job activities is representative for these types of jobs in south central Iowa. The model designates the off-farm job activities as zero/one integer variables. In addition the model is structured so that the husband and wife are restricted to holding only one off-farm job each. A brief description of the off-farm job variables is included in Table 5.

Capital constraints

Borrowing and lending activities are included in the model so that interest charges are made implicitly in the model. No limits are placed on the borrowing or lending activities. The farm is given an initial endowment of $10,000 of capital. The model sets the interest rates at .9 percent per month for borrowing and at .5 percent per month for savings.

Table 5. List and definition of selected variables in the normative model

JOB1	A full-time off-farm job for the wife during the daytime, 40 hours per week at $7.50 per hour for 50 weeks during the year.
JOB2	A part-time off-farm job for the wife during the daytime, 20 hours per week at $6.00 per hour for 50 weeks during the year.

Table 5. Continued

JOB3	A part-time off-farm job for the husband during the daytime, 30 hours per week for 50 weeks during the year at $7.00 per hour.
JOB4	A part-time off-farm job for the husband during the daytime, 20 hours per week 50 weeks a year at $6.00 per hour.
JOB5	A seasonal part-time off-farm job for the husband during the daytime, 20 hours per week during November through March (20 weeks) at $5.50 per hour.
CSBL1	A corn-soybean crop rotation activity on class 1 land.
CSBL2	A corn-soybean crop rotation activity on class 2 land.
CCCOMM3	A corn-corn-corn-oats-meadow-meadow (CCCOMM) crop rotation activity on class 3 land.
CCOMM3	A CCOMM crop rotation activity on class 3 land.
PASTURE3	A pasture growing and maintenance activity on class 3 land. Assumes bromegrass pasture is already established on class 3 land.
FEEDSTR	A steer feeding activity that places 450 lb feeder steers in a feedlot to be fed to slaughter weight.
GRAZESTR	A steer feeding activity that winters 450 lb feeder steers in the feedlot and then places them on pasture during the summer before finishing these steers out the following winter.
FPBUY02 - FPBUY12	A feeder pig purchasing activity for one 50 lb pig in the corresponding months of February, April, June, August, October, and December.
FPIG02 - FPIG12	A feeder pig feeding activity for one 50 lb pig purchased in the corresponding months of February, April, June, August, October, and December.
FPSELL02 - FPSELL12	A feeder pig selling activity for one 50 lb pig in the corresponding months of February, April, June, August, October, and December.
HOGFAR1	A pig production activity with sows farrowing in February and August. The unit of production is one sow and two litters.

Table 5. Continued

HOGFAR2	A pig production activity with sows farrowing in April and October.
HOGFAR3	A pig production activity with sows farrowing in June and December.
RENTL12	An activity to cash lease out one acre of cropland which is equally divided between class 1 and class 2 land.
RENTL3	An activity to cash lease out one acre of class 3 land.
L12RENT	An activity to cash rent additional cropland which is made up of equal proportions of class 1 and class 2 land.
LHIRE04 - LHIRE11	A labor hiring activity at $4.50 per hour for the corresponding months of April, May, June, July, August, September, October, and November.

RESULTS OF THE NORMATIVE MODEL

The base solution with all off-farm job activities available, shown in Table 6, has an objective function value of $59,806. The model selects the seasonal part-time job for the husband (JOB5) and the full-time off-farm job for the wife (JOB1), which is higher paying than the husband's full-time job. Therefore, this farm can be classified as a part-time farming operation which consists of raising crops and feeding cattle and hogs. All of the available additional cropland is rented (300 acres). The owned and rented class 1 and 2 land (a total of 500 acres) is cropped in a corn-soybean rotation. All except one acre of the owned class 3 land is cash rented out for a relatively low cash rent of $30 per acre. Thus, the returns to farming this low quality land do not offset the opportunity costs of the labor required. The livestock enterprises consist of feeding 514 head of hogs and 160 head of steers to market weight each year. An income statement detailing the revenues and expenses generated from each enterprise is shown in the Appendix.

The model utilizes the maximum amount of labor jointly available from both the husband and wife. The husband provides 796 hours of the 1,200 hours of household maintenance labor required directly and indirectly by the model, thereby allowing the wife to take full-time off-farm employment. In addition, the maximum amount of labor is hired in May (160 hours) and 108 hours of labor are hired in October.

Table 6. Optimal solutions to the normative model for the base case and for selected sensitivity analysis cases

Solution No.	Base Solution	S1[a]	S2[b]	S3[c]	S4[d]	S5[e]	S6[f]	S7[g]	S8[h]	S9[i]	S10[j]
Obj. fn. value	59,806	52,824	64,731	59,088	62,910	52,949	56,226	59,045	58,258	75,140	56,020
JOB1	1	N.A.	1	1	1	1	1	1	1	1	1
JOB2		N.A.									
JOB3		N.A.	1								
JOB4		N.A.									
JOB5	1	N.A.	N.A.	1	1	1	1	1	1	1	1
CCOMM3 ac.	1	60				28					
CCCOMM3 ac.									24		
CSBL1 ac.	250	250	164	244	217	250	230	249	200	228	216
CSBL2 ac.	250	250	164	244	217	250	230	249	200	228	216
PASTURE3				100							
FEEDSTR hd.	160	100	140	77	80	160	140	140	140	200	
GRAZESTR hd.				83							
FPBUY02 hd.											1
FPBUY04 hd.	100		100	100	29		100	100	1	300	83
FPBUY06 hd.	300		300	300	55	100	300	300	83	300	1
FPBUY08 hd.	57		100	57	29	57	100	100		286	83
FPBUY10 hd.											1
FPBUY12 hd.	57		100	57	29	57	100	100		286	83
FPIG02 hd.											118
FPIG04 hd.	100	35	100	100	146		100	100	118	300	200
FPIG06 hd.	300	200	300	300	171	100	300	300	200	300	118
FPIG08 hd.	57	21	100	57	146	57	100	100	18	286	200
FPIG10 hd.											118
FPIG12 hd.	57	21	100	57	146	57	100	100	18	286	200
FPSELL02 hd.		234			117				117		
FPSELL04 hd.		198									
FPSELL06 hd.		34									
FPSELL08 hd.		212							99		
FPSELL10 hd.		234			117				117		
FPSELL12 hd.		212							99		
HOGFAR1 sows		32			16				16		16
HOGFAR2 sows		32			16				16		16
HOGFAR3 sows		32			16				16		16
HOGSELL cwt.	1137	614	1326	1137	1349	474	1326	1326	780	2589	2106
RENTL12 ac.											
RENTL3 ac.	99	38	100		100	72	100	100	76	100	100
L12RENT ac.	300	300	128	288	235	300	260	298	200	256	232
LHIRE04 hrs.											
LHIRE05 hrs.	160	160	120	160	160	160	160	160	160	160	160
LHIRE06 hrs.			92								
LHIRE07 hrs.			147								
LHIRE08 hrs.			67								
LHIRE09 hrs.			140								
LHIRE10 hrs.	108	106	160	137	125	122	109	113	98	107	139
LHIRE11 hrs.			132						31		

[a]Assumes situation in which no off-farm jobs are available.

[b]Assumes that JOB5 is unavailable and a 30 percent increase in all job wage levels creating a full employment situation.

[c]Assumes that class 3 land cannot be cash rented out.

[d]Assumes there is a five percent increase in all hog prices.

[e]Assumes there is a 20 percent decrease in all hog prices.

[f]Assumes that it requires 1.2 hours and 1.5 hours of wife's and children's labor, respectively, to equal one principal farm operator equivalent hour.

[g]Assumes that the labor requirements for cattle feeding are increased by 20 percent.

hAssumes that farm size is limited by only allowing 200 acres of additional cropland to be rented.

[i]Assumes that the available facility space is increased from 2,800 square feet to 5,000 square feet.

[j]Imposes an "either-or" constraint on the selection of either cattle feeding or hog feeding enterprises.

May is the most constraining month for labor. An additional hour of hired labor in May would increase the value of the objective function by about $37. The livestock facilities are under-utilized in the months of March, April, May, and October because of the high seasonal labor demands of the crop enterprises.

While the shadow price for May labor is very high in the base solution, the upper bound of 160 hours on hiring May labor can be realistically justified based on seasonal labor market patterns. Seasonal part-time labor during planting and harvesting periods is in high demand and may be difficult to obtain. The most likely sources of labor are high school students who are available but are limited from four to six hours per day at the maximum and retired farmers who are also unlikely to work full days. Secondly, hired labor of this type usually needs supervision by the farm operator. Therefore, the amount of labor that can be hired is also limited by the farmer's own supervision capacity which decreases when the farmer is employed off the farm.

The initial solution to the normative model does not support the hypothesis that beef cow-calf enterprises are selected by part-time farmers. It does support the hypothesis that sow farrowing enterprises are less likely to be selected by part-time farmers because of their high labor and capital requirements. The hypothesis that hog feeding enterprises are selected when livestock facilities are available at a low opportunity cost is also supported by these results. In an effort to further test the validity or invalidity of the hypotheses postulated from the positive analysis under a wide array of situational assumptions for this representative farm family, a sensitivity analysis of the normative model was performed.

Sensitivity Analysis

The traditional range analysis of a noninteger LP model cannot be validly interpreted for a mixed integer LP problem. Therefore, the sensitivity analysis of this model was performed by reoptimizing the model under different sets of conditional assumptions to obtain alternative solutions. The changes in the "new" optimal solution relative to the base solution are analyzed to obtain general trends and insights. This type of sensitivity analysis allows one to access the effects of changes in a set of coefficients on the optimal solution versus just one coefficient. The robustness of the results from the representative farm model to many types of farming situations, resource endowments, and price levels can be tested in this manner. When the optimal solution is determined by complex interactions among many variables, sensitivity analysis provides additional information about the strength or weakness of the initial results.

Off-farm job sensitivity

The model was analyzed to determine the effects of the presence or absence of potential off-farm jobs on the optimal farm plan. When the seasonal part-time job for the husband (JOB5) is unavailable, the model will only select the wife's full-time job (JOB1). In this situation the husband's labor is more profitably employed on the farm rather than in another off-farm job. In the situation where JOB1 is unavailable in the model, the full-time job for the husband (JOB3) is selected. Since the wife now has more labor available for the farming operation, the husband switches to a more labor intensive off-farm job as expected. This indicates that a combination of the husband's and wife's labor resources in excess of one full-time job and a seasonal part-time job are more effectively employed in the farming operation.

The results of the model are relatively insensitive to changes in the general wage levels since there is no change in the optimal solution within a range of wages that are 25 percent lower to 30 percent higher than the initial wage levels. A 30 percent decrease in the wage levels causes JOB1 to drop out of the optimal solution leaving only JOB5 in the solution. This translates into a reservation wage for JOB1 somewhere between $5.25 to $5.62 per hour. JOB5, which utilizes residual labor available during the slack winter months when there is little labor demanded by crop enterprises, is found to have a reservation wage lower than $3.30 per hour which is below the legislated minimum wage rate.

In order for the model to select both the husband's and wife's full-time jobs, JOB3 and JOB1, when all jobs are available the general level of wages had to be increased by 35 percent.

The sensitivity analysis shows that off-farm employment improves net family income. Off-farm jobs which have constant marginal returns to labor for given blocks of time are optimal even at relatively low wage rates because there are diminishing marginal returns to farm labor, especially for seasonal part-time employment which utilizes excess labor resources during periods of low farm labor demand.

Enterprise sensitivity

The crop and livestock activities selected under different off-farm job availability situations are also of interest. The cow-calf, sheep, and feeder lamb enterprises do not enter the optimal solution in any of the off-farm employment situations analyzed above. The optimal farm plan for the base case of the model includes feeding hogs and cattle. The sow farrowing enterprise is not included in the initial solution but does enter the solution when no full-time off-farm employment is available as shown by solution S1 in Table 6.

The corn-soybean rotation is the most profitable cropping activity for class 1 and 2 land. The model will cash rent out all of the class 3 land if possible, otherwise this land will be utilized as pasture for grazing steers (S3, Table 6). If class 3 land cannot be cash rented out and there are no off-farm jobs available, the farmer will place all of the class 3 land in a CCOMM crop rotation instead of utilizing the land as pasture for the GRAZESTR activity.

When both the husband and wife are employed in full-time off-farm jobs, the farm operation consists of feeding 600 head of purchased pigs along with 140 head of feeder steers each year (S2, Table 6). The husband and wife together can only contribute 1400 additional hours to the farming operation, so 898 hours of additional seasonal labor is hired in the months of May through November to operate the farm at this level.

The labor requirements of the off-farm jobs cause the model to adjust the levels of the crop and livestock activities in the farming operation accordingly. As expected, the level of the sow farrowing enterprise is inversely related to the level of off-farm employment.

The sensitivity of enterprise selection to the blocked production facilities is considered by allowing the fixed cost activities to be noninteger. The model will include the sow farrowing enterprise at minimal levels in each period (1.37 sows) when the facility size is completely flexible.

The fact that the cow-calf enterprises are not included in the model's optimal farm plans is in direct contrast to empirical observations of south central Iowa farms. One reasonable scenario (not shown in Table 6) in which the cow-calf enterprise does enter the solution (40 head COWCALF) is under the assumptions of no available off-farm jobs, relatively high feeder cattle prices, and no alternative uses for the low quality class 3 land except for pasture or continuous hay. The prices for feeder cattle and slaughter cattle in that case were as follows: slaughter steers at $71.79 per cwt., slaughter heifers at $69.29 per cwt., feeder steers (450 lbs) at $92 per cwt., and feeder heifers (400 lbs) at $81 per cwt. Even with high feeder cattle prices the cow-calf enterprise only enters the solution when full-time off-farm employment is unavailable.

If class 3 land is restricted to either pasture or hay and all off-farm employment is unavailable, a 20 percent decline in hog prices results in an optimal solution which includes 43 head of grazing steers and 20 head of cows whose calves are fed to market weight.

Under the extreme assumptions of zero labor requirements and no fixed cost charges for the cow-calf enterprises when the use of class 3 land was restricted to either pasture or hay, the optimal solution still did not include beef cow-calf enterprises. This case (not shown in Table 6) clearly demonstrates that the nonoptimality of beef cow-calf enterprises does not depend on the labor requirements or fixed costs assumptions of the model.

Price sensitivity

The optimal solution of the model is sensitive to an increase in the general level of hog prices and less sensitive to a decrease in hog prices. An increase in both feeder pig and slaughter hog prices of just five percent causes a dramatic shift in the optimal solution to include farrowing 16 sows in each period along with a slight increase in hog feeding (S4, Table 6). Further increases in hog prices cause a continued increase in the sow farrowing activities and corresponding decreases in the steer feeding enterprise. Conversely, a decrease in hog prices by ten percent results in no change, but a decrease in hog prices by 20 percent causes a severe reduction in hog feeding from 514 head to only 214 head (S5, Table 6).

The sheep enterprise is only optimal when there are extremely high lamb prices and so is not a likely enterprise choice. The feeder lamb feeding enterprise is a possible alternative if low hog prices or very high lamb prices are expected.

In general, a ten percent decrease in either corn or soybean prices while holding other prices the same results in a decrease in the acres of crop land rented, thereby decreasing the acreage of corn and soybeans. This also causes the sow farrowing enterprise to be included in the optimal solution. To accommodate the sow farrowing enterprise, the number of cattle and hogs fed are reduced. However, the same off-farm jobs are selected.

A 20 percent decrease in the price of soybeans alone causes a decrease in the acres of corn-soybean rotation but does not cause a shift to continuous corn or other crop rotations. Therefore, the selection of the corn-soybean rotation as the optimal crop rotation for the farm is very robust to changes in relative crop prices.

A decline in both corn and soybean prices by 20 percent causes the optimal solution to shift both the husband and wife into full-time off-farm employment. In this solution there is no sow farrowing and a substantial decrease in corn and soybean acreage occurs. Additional labor is hired to support the feeding of 160 head of steers and 514 head of hogs.

Labor requirement sensitivity

When the model's sensitivity to changes in the labor coefficients for the sow farrowing activities was tested, a ten percent decrease in the labor requirements for the sow farrowing enterprise did not change the optimal solution. Increasing the labor requirements for the cattle feeding enterprises ten to 20 percent causes only a slight decrease in the steer feeding activity from 160 head to 140 head. This decrease in steer feeding is offset by an increase in the number of hogs fed from 514 head to 600 head. The 20 percent increase in labor usage by the steer feeding enterprise also causes a slight decrease in crop production activities (S7, Table 6).

Labor endowments The initial assumption that the husband and wife are each willing to work 3,000 hours per year including labor for household chores may clearly be too ambitious for some individuals' preferences. The husband's and wife's total annual labor availability can be reduced to 2,500 hours per year without changing the optimal choice of off-farm jobs or significantly changing the optimal levels of the farm enterprises. This decrease in labor availability is compensated for by hiring additional farm labor.

If the model assumes that the husband and wife are each willing to work only 2,050 hours per year then the optimal solution includes the part-time job for the wife (JOB2) and the seasonal part-time job for the husband (JOB5). The levels of the livestock enterprises remain the same in this case, but crop production increases with all of the class 3 land placed in a CCCOMM rotation. The hours of additional farm labor hired increases to 1,097 hours in this case. In general, as the number of hours the farm family is willing to work decreases, the level of off-farm employment will also tend to decrease with the level of farm enterprises staying the same or increasing.

Labor substitution ratios Changing the labor substitution ratios for different family members indirectly affects farm labor availability or, more specifically, the availability of principal operator equivalent hours of labor. It does not affect the amount of labor required for household commitments. In this analysis, the efficiency of the wife's and the children's labor for farm work relative to off-farm employment was decreased by assuming that it requires 1.2 hours of the wife's labor and 1.5 hours of the children's labor to equal one principal farm operator equivalent hour (S6, Table 6). These results indicate that if part-time farm families are on average relatively less efficient producers than full-time farm families, then the part-time farmers may slightly favor hog feeding enterprises over cattle feeding enterprises.

Labor hiring activities In some situations the assumption that additional farm labor can be hired on an hourly basis each month with no guarantees for a minimum number of hours or for continued employment in the next month may be unrealistic. A more realistic constraint may be to only allow the farmer to hire minimum blocks of 80 hours of labor per month either year round or seasonally from April through November. The results show that because of the high shadow price on May labor the farmer is willing to hire an employee 160 hours per month year round in order to maintain the same enterprise levels and off-farm employment as in the base solution. This farm employee is hired at $4.50 per hour, but because of the assumption that hired farm labor is less efficient the effective cost of hiring additional labor is $5.40 per "principal operator equivalent hour."

If we assume the cost of hired farm labor increases to $5.50 per hour or $6.60 per principal operator equivalent hour, then the farmer is only willing to hire an additional 160 hours per month seasonally in April through November. When farm labor can only be hired on a year-round basis, the farm family hires only 80 hours of farm labor per month and keeps the same off-farm jobs (JOB1 and JOB5). This requires a decrease in the acreage of corn and soybeans because of the May labor constraint. Although the May labor constraint has a very high shadow price, it is still more profitable for the wife to be employed in a year-round full-time off-farm job than it would be for the wife to provide additional May labor on the farm by decreasing her level of off-farm employment.

Farm size sensitivity

When permitted to only rent up to 200 acres of crop land, the model will rent all the available land, utilize 24 acres of the low quality class 3 land in a CCCOMM rotation, and maintain the same off-farm jobs (S8, Table 6). The livestock enterprises now include farrowing 16 sows in each period thereby reducing the number of hogs fed out annually to 353 head. The number of steers fed in the feedlot also decreases to 140 head.

When the size of the farm is limited by not allowing any additional land to be rented, the farm family responds by increasing both the husband's and wife's off-farm employment to full-time. This results in a shift from steer to heifer feeding and the utilization of all class 3 land in a CCCOMM rotation. The level of hog and cattle feeding remains the same and the class 1 and 2 land is placed in a corn-soybean rotation. Additional farm labor is hired during the months of May through November to support these activities. This result is consistent with the belief that some part-time farming operations exist because of farm size limitations.

If the upper bound on the acreage of cropland that can be rented is relaxed, only eight additional acres are rented because of the constraint on May labor. However, renting additional land does cause a decrease in cattle feeding and an increase in hog feeding.

Facility capacity Relaxing the common livestock facilities space constraint from 2800 square feet to 5000 square feet causes the farm operation to become more hog and cattle feeding intensive (S9, Table 6). The number of hogs fed annually more than doubles from 514 head to 1,171 head and the number of steers fed increases from 160 head to 200 head which is the upper bound for the model. The same off-farm jobs are also selected by the husband and wife (JOB1 and JOB5) in this situation. Thus, even if livestock facilities are not as limiting, the farmer would choose to employ the same amount of labor in the farming operation although allocating this labor differently among the farm enterprises.

If the common livestock facilities space constraint is made more binding by reducing the available space to 2000 square feet, the level of cattle and hog feeding enterprises decreases substantially, crop production increases, and the same off-farm employment for the husband and wife is maintained. Therefore, there is a direct relationship between the level of cattle and hog feeding and the availability of the livestock facility space. However, the selection of off-farm employment is relatively insensitive to the availability of livestock facilities.

Enterprise specialization

Up to this point we have assumed that the available livestock facilities can be used for either cattle or hogs, or jointly for both at the same time. It is also reasonable to assume that the livestock facilities are specialized and can only be adapted to either cattle or hogs but not both simultaneously. Another justification of this assumption is that because of specialization of the farmer's management skills to one species, the farmer may not be competent to manage both hog and cattle enterprises. When this "either-or" constraint is imposed the model selects the hog feeding enterprise in all off-farm employment situations. Given this constraint, the hog feeding enterprise is combined with the sow farrowing enterprise in the optimal solution (S10, Table 6). This solution almost completely utilizes all the facility space throughout the entire year.

Summary of the Normative Results

In general, the results of the sensitivity analysis show that the normative model is robust. The optimal enterprises and off-farm jobs chosen do not make any significant changes with moderate changes in price levels, labor requirements, or facility endowments.

These results show that hog and cattle feeding enterprises are likely to be chosen by part-time farmers in many different situations. This generally supports the hypothesis that hog feeding enterprises are adaptable to part-time farming operations. The results also show that hog feeding is preferred to cattle feeding due to facility or management specialization. However, cattle feeding is shown to be more compatible with part-time farming than sow farrowing enterprises when the farmer has the ability to utilize facilities for both cattle and hogs.

Sow farrowing enterprises are an optimal enterprise choice of the normative model when no full-time jobs are available for either the husband or the wife. The level of the sow farrowing enterprise moves inversely with level of off-farm employment due to the enterprise's relatively high labor requirements. In situations when the sow farrowing enterprise does enter the optimal solution, the farrowing facility is utilized at full capacity in most situations.

The optimality of the sow farrowing enterprise is fairly sensitive to the initial assumptions in general and specifically to relative price levels. An increase in the relative level of hog prices makes sow farrowing an optimal enterprise choice. Therefore, the normative results only can be said to support the hypothesis made from the positive analysis at the relative hog price levels assumed or lower.

The results from the normative model do not support all of the hypotheses implied by the positive analysis. Specifically, the results from the normative model show that beef cow-calf enterprises are rarely optimal. Only under special circumstances will the model select cow-calf enterprises and these results seem to indicate that the selection of the cow-calf enterprise is more likely when there is little or no off-farm employment. These circumstances do represent the resource endowments of many full-time farmers in south central Iowa who do not have any realistic off-farm employment opportunities and have limited alternative uses for their land besides pasture. The questionable assumption is that of high feeder cattle prices. If historical price relationships are assumed then the farmer should choose feeder cattle grazing activities over cow-calf enterprises.

A final explanation for the inconsistencies between the positive and normative results is that the normative model assumes the farm family's single goal is to maximize profits (or net income) whereas in reality the farm family may have other goals and objectives which lead to their observed behavior. Therefore, the more appropriate paradigm may be the maximization of expected utility. If the farm family is risk neutral it can be easily shown that profit maximization is equivalent to the maximization of expected utility. However, if the farm family is risk averse then a model which explicitly incorporates risk will more accurately reflect the farm family's enterprise choices.

THE NORMATIVE MODEL WITH RISK

In order to consider risk in the model and also include integer variables, a linear form for risk was used instead of quadratic risk programming methods. The "target MOTAD" framework is selected as the method for including risk in this MILP model. Target MOTAD maximizes mean income subject to a limit on the total negative deviations measured from a fixed target rather than from the mean (Tauer, 1983; Watts et al., 1984).

Target MOTAD has the advantage of selecting solutions which are members of the second-degree stochastic dominance (SSD) efficient set, whereas ordinary MOTAD does not necessarily have this property. Thus, target MOTAD is one way to generate a partial set of SSD efficient solutions.

The minimization of the total absolute negative deviations from a target level of income also captures some of the same ideas and motivations for the safety-first approach of decision making. A safety-first criterion may be more appropriate for modeling the behavior of limited resource farmers or small-sized farms which are frequently part-time farmers as well.

Adapting the Certainty LP Model

The original normative LP model was simplified to accommodate the complexity of incorporating risk into this model. The size of the model was reduced by eliminating the activities and rows needed for the differential labor substitution ratios by assuming that each spouse's labor is a perfect substitute for one another on the farm. Furthermore, no distinction is made between labor provided in the daytime versus the evening. The children's labor contribution is eliminated from the model which is compensated for by adjusting the labor constraints of the parents. The upper bounds on the labor hiring activities were decreased to account for the lower efficiency of hired labor[1].

The target MOTAD model requires an historical revenue or price series over a period of years from which each year's negative deviation from the target income level is calculated. Risk is incorporated into this target MOTAD model through stochastic prices and crop yields for the farm enterprises. Livestock production output was assumed to be nonstochastic. Historical prices and yields for south central Iowa over a six-year period (1981-1986) were used to calculate the negative deviations from the target income level in each year with each year's data given an equal weight. Stochastic crop yields are implicitly reflected in yield adjusted crop prices. Prices were converted to a 1986 basis using the implicit GNP price deflator to adjust the historical gross returns of the farm activities to 1986 production costs. All costs and the wages from off-farm jobs are assumed to be known with certainty. The adjusted stochastic price series was inserted

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[1]The cost of the hired labor was not increased to adjust for its lower efficiency causing the objective function values of the target MOTAD solutions to be slightly higher.

into a target MOTAD matrix to derive risk-income pairs and the associated enterprise combinations.

Results from the Target MOTAD Model

The selection of a given solution by the target MOTAD model depends on the farmer's level of risk aversion which is represented by his acceptable level of target income and the acceptable level of expected negative deviations from that target. For a given target level of income the farmer's level of risk aversion is inversely related to the absolute value of expected negative deviations. As the parameter representing absolute value of expected negative deviations (L) becomes large, the farmer will behave as if he were risk neutral. The more risk averse farmer sacrifices expected mean net income for less variability below a target income level.

Solutions for the model were obtained at three different target levels of income, \$45,000, \$50,000 and \$55,000, by varying L from 0 to 10,000. These target MOTAD solutions are compared to the solution for the model under the assumption of certainty in Table 7. The optimal solutions at different degrees of risk aversion provide useful insights about the changes in the farm enterprise mix caused by including risk in the model.

The same risk neutral solution was found for all three target income levels when the allowed absolute value of expected negative deviations exceeded a certain limit. The risk neutral target MOTAD solution is equivalent to the solution obtained by assuming certain

Table 7. Trade-offs between risk and mean income with associated enterprise combinations for target MOTAD at selected targets and negative deviations

Solution no.	Certainty solution	1	2	3	4	5	6	7	8	9	10
Mean net income	61,110	60,934	58,335	58,181	54,324	54,179	58,178	54,198	54,021	55,359	53,901
Target income		45,000	45,000	45,000	45,000	45,000	50,000	50,000	50,000	55,000	55,000
Expected neg. deviations		2,250	1,900	1,400	1,250	1,050	3,500	3,250	3,050	5,900	5,800
JOB1	1	1	1	1	1	1	1	1	1	1	1
JOB2											
JOB3										1	
JOB4											
JOB5	1	1	1	1	1	1	1	1	1		1
CCOMM3 ac.	1	2									
CCOMM3 ac.											
CSBL1 ac.	250	250	235	223	198	191	221	192	184	165	180
CSBL2 ac.	250	250	235	223	198	191	221	192	184	164	180
FPBUY02 hd.											
FPBUY04 hd.	100	150		20			16			200	
FPBUY06 hd.	300	250	250	137	99	19	126	26		200	
FPBUY08 hd.	57	100								186	
FPBUY10 hd.											
FPBUY12 hd.	57	100	145	59	10		44			186	
FPIG02 hd.											
FPIG04 hd.	100	150	109	137	82	121	133	124	104	200	93
FPIG06 hd.	300	250	250	200	200	150	200	150	150	200	150

FPIG08 hd.	57	100	103	103	64	64	103	64	64	186	64
FPIG10 hd.											
FPIG12 hd.	57	100	145	122	111	100	118	103	83	186	72
FPSELL02 hd.			117	117	234	234	117	234	234		234
FPSELL04 hd.			8		151	112		109	129		141
FPSELL06 hd.									30		62
FPSELL08 hd.			13	13	170	170	13	170	170		170
FPSELL10 hd.			117	117	234	234	117	234	234		234
FPSELL12 hd.						31		21	97		141
HOGFAR1 sows			16	16	32	32	16	32	32		32
HOGFAR2 sows				9	14	18	10	17	25		29
HOGFAR3 sow			16	16	32	32	16	32	32		32
HOGSELL cwt.	1137	1326	1341	1243	1010	963	1225	975	886	1705	837
FEEDSTR hd.	160	140	100	100	80	80	100	80	80	100	80
RENTL12 ac.											
RENTL3 ac.	99	98	100	100	100	100	100	58	100	100	100
L12RENT ac.	300	300	270	246	197	181	243	184	168	129	159
LHIRE04 hrs.									38	71	84
LHIRE05 hrs.	133	133	133	133	133	133	133	133	133	133	133
LHIRE06 hrs.					110	133		122	167	167	167
LHIRE07 hrs.					167	167		167	167	167	167
LHIRE08 hrs.					167	167	13	167	167	167	167
LHIRE09 hrs.			60	130	133	133	133	133	133	133	133
LHIRE10 hrs.	89	91	133	133	133	133	133	133	133	133	133
LHIRE11 hrs.			133	133	133	133	133	133	133	133	133

returns in the same model. The expected mean net income for the risk neutral solution is $61,110. The crop and livestock activity levels for the risk neutral target MOTAD solution is almost exactly the same as for the larger normative model discussed earlier.

In general, increased risk aversion is expressed by adding the sow farrowing enterprise to diversify the farming operation. In order to add the farrowing enterprise, labor resources shift out of the crop production and other livestock activities. As risk aversion gradually increases, the number of hogs fed is increased and the number of steer calves fed is reduced. When the sow farrowing enterprise enters the optimal solution, the acreage of corn-soybean rotation is reduced by renting less cropland as shown in Table 7. A highly risk averse farmer will farrow as many as 32 sows in two of the three farrowing periods selling most of the pigs as feeders and decreasing the total number of hogs finished for market. This risk averse farmer does not change his level of off-farm employment but instead increases the amount of labor hired in order to support the sow farrowing activities. Therefore we must infer that the inclusion of the sow farrowing enterprise improves income stability and that risk is better handled by changing the farm enterprise mix rather than the level of off-farm employment in this situation.

Solution number 9 in Table 7 represents one case at a specific level of risk aversion where the choice of full-time off-farm employment for the husband and wife is preferred over the selection of the sow farrowing enterprise. These results show that increasing the level of off-farm employment is also a way that the farm family can avert risk. One should note, however, that at a higher level of risk aversion for the same target income level (solution number 10), the sow farrowing enterprise, is once again preferred over an increase in off-farm employment. The apparent inconsistency of the model's results can be explained by the blocking of the fixed costs for the sow farrowing facilities and the all or none nature of taking an off-farm job.

The inclusion of the sow farrowing enterprise in the risk averse solutions represents enterprise diversification which is a common response to risk. Other activities such as sheep or cow-calf enterprises which could have been chosen as a means of diversifying the farming operation were not included in any of the optimal solutions. However, this may be due to the fact that only seven years of historical data were used to estimate the riskiness of the farm activities and that 1980 to 1986 was a period of low returns for cow-calf producers. Different results may have been obtained if a longer historical time series of prices spanning the price and production cycles of cattle and sheep were used, although past price relationships do not necessarily accurately represent present price relationships. A further danger of using long historical price series is the failure to account for structural changes in demand and price relationships.

SUMMARY OF THE IMPLICATIONS DRAWN FROM THE NORMATIVE ANALYSIS

The normative analysis shows that part-time farming can be an optimal strategy with given resource limitations and available off-farm employment opportunities. In many cases part-time farmers benefit by expanding livestock enterprises which have relatively high expected returns and reducing the level of crop production.

The normative analysis indicates that the livestock enterprises which "best" fit into part-time farming operations are hog feeding and cattle feeding. The hog feeding enterprise and the sow farrowing enterprise complement each other, especially when the facilities can only accommodate one type of livestock. The results show that the level of the sow farrowing enterprise is inversely related to the level of off-farm employment. Cattle feeding is another enterprise which works well in part-time farming operations either by itself or in combination with hog feeding enterprises.

The normative analysis implies that seasonal part-time employment is a bonus for most farm situations because it utilizes otherwise unused labor resources of the farm family. Furthermore, for farms with the size and resource limitations outlined in the previous section, at least one farm family member should hold a full-time off-farm job.

Implications can also be drawn from what enterprises do not enter the optimal solutions of the normative model. Beef cow-calf enterprises are not optimal enterprise choices for part-time farmers and only become optimal under special circumstances and assumptions. Furthermore, cow-calf enterprises appear to be inversely related to off-farm employment.

COMPARISON OF THE RESULTS FROM THE POSITIVE AND NORMATIVE MODELS

This paper began with a positive analysis of the relationship between part-time farming operations and the selection of livestock enterprises in each county in Iowa. These results led to several specific assumptions and hypotheses which were used to provide direction in the construction and analysis of the normative model. The results generated from the normative model provide a means of testing the hypotheses of the positive analysis.

The first hypothesis, that beef cow-calf enterprises will be selected by part-time farmers, is rejected by the normative results. The beef cow-calf enterprises entered the optimal solution of the normative model only under special circumstances discussed earlier. There are several possible reasons or explanations for this "difference of opinion" between the two models. First, the positive relationship between part-time farming and cow-calf enterprises may be spurious and thus controlled by other mutual factors.

Another possibility is that the normative model may be incorrectly specified. If historic price averages from a period of time which favors hogs relative to other enterprises are used, then hogs will be the dominant enterprise in the solution. The sensitivity analysis shows that moderate changes in hog prices will cause the optimal solution to become more crop intensive but not include cow-calf enterprises.

Beef cow herds are often looked upon as a supplemental enterprise which are valuable in utilizing otherwise wasted resources such as gleaning corn fields and nontillable land in pasture. The synergistic relationships between beef cow-calf enterprises and other enterprises are not accounted for in the basic normative model so attempts to compensate for synergisms were made during the sensitivity analysis. The sensitivity analysis results show that extreme alterations in assumptions are needed for the cow-calf enterprises to enter the optimal solution, and so it is unlikely that the failure to account for synergisms affected the optimal solution of the base case. However, one of the assumptions that low quality land can only be used for pasture is realistically justified for some farms in the south central region of Iowa. If in addition one can also assume relatively high feeder cattle prices and no off-farm employment opportunities or, conversely, relatively low hog prices, then cow-calf enterprises will be included in the optimal solution.

The optimal solutions from the normative model with risk also do not include cow-calf enterprises at any level of risk aversion. However, the explicit consideration of risk averse behavior by part-time farmers does indicate a tendency to diversify the farm enterprise mix. Specifically, the risk neutral solution of the risk model did not include sow farrowing but as the level of risk aversion increases sow farrowing is included in and also increases in the optimal solution.

A final explanation offered for an incorrectly specified model is that farmers in general and part-time farmers in particular have motives and objectives other than the maximization of net family income.

The second hypothesis made was that sow farrowing enterprises require more labor and capital than most part-time farmers are able to commit to operate on an efficient scale and so will be chosen less often by part-time farmers. The results of the normative model here are somewhat inconclusive. On one hand the normative results clearly establish that there is an inverse relationship between off-farm employment and the sow farrowing enterprise. On the other hand the optimal solution for many part-time farming situations does include the sow farrowing enterprise. The level of the sow farrowing enterprise is fairly sensitive to changes in relative prices. In addition, if the part-time farmer is risk averse then including the sow farrowing enterprise along with other enterprises is more attractive because of its income stabilizing effects.

The third hypothesis, that hog feeding may be important in part-time farming operations depending on the specific circumstances, is supported by the normative results. The optimal solution does include the hog feeding enterprise in most situations under the assumption that the farmer has available livestock facilities which can be adapted to any livestock enterprise. The sensitivity analysis indicates that if the available space in the livestock facilities is made more limiting then the amount of hog feeding decreases.

Future research efforts should attempt to retest the positive hypotheses using sample data which identifies individual farms.

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APPENDIX

Income Statement for the the Base Normative Model's Results

	Activity Level	Obj Fn Value	Total Dollars	Net Income
INCOME SOURCES				
Net Income from Off-farm Jobs				17200.00
Crop Production Enterprises				
Crop Sales:				
Corn	11330.52	2.67	30252.49	
Soybeans	8250.00	6.28	51810.00	
Oats	7.32	1.80	13.18	
Total Crop Sales			82075.66	
Total Value Of Crops Used by Livestock			44952.22	
Total Crop Production Expenses			49713.41	
Net Rental Income			-19827.60	
Net Income from Crops				57486.88
Hog Production Enterprises				
Slaughter Hog Sales:	1136.57	53.25	60522.35	
Hog Production Expenses				
Feeder Pig Purch.	514	49.65	25534.00	
Hog Feeding	514	21.44	11026.16	
Value of Corn Used	5142	2.67	13731.28	
Total Hog Production Expenses			50291.44	
Total Fixed Production Costs			2025.00	
Net Income from Hog Enterprises				8205.91
Cattle Enterprises				
Steer Feeding	160		58326.40	
Total Gross Income from Cattle Sales			58326.40	
Cattle Production Expenses				
Value of Corn Used	11680	2.67	31185.60	
HAYBUY	111	36.00	3995.64	
Value of Hay Used	1	35.00	35.23	
PASTURE3	0	22.45		
Total Production Expenses			35216.47	
Total Fixed Costs			4000.00	
Net Income from Cattle Enterprises				19109.93
Net Interest Income				-941.70

Income Statement for the Normative Model's Base Solution (Continued)

	Activity Level	Obj Fn Value	Total Dollars	Net Income
Non-Allocated Overhead Expenses				
Total Hired Labor Expense			1204.61	
Total Other Fixed Expenses			40050.00	
Total Non-Allocated Overhead Expenses				41254.61
TOTAL NET INCOME				59806.41

SECTION II. A MULTIPERIOD EVALUATION OF ALTERNATIVE STRATEGIES FOR IOWA BEEF COW-CALF PRODUCERS

INTRODUCTION

The beef cow-calf enterprise has been an integral part of many farming operations in Iowa. Beef cows and other ruminant animals have the ability to utilize forages produced from poor quality land resources by pasture grazing or through the feeding of mechanically harvested forages. This type of enterprise is especially important in southern Iowa where a large proportion of the farmland is not suited to long-term intensive crop production. From a soil and water conservation aspect, the beef cow-calf enterprise may produce societal benefits by reducing the acres of highly erodible land under cultivation and reducing groundwater contamination from pesticides. Unfortunately, agricultural policies and economic conditions over the past 10 years have encouraged the liquidation of cow herds and an increase in cash-grain crop farming in these areas. The decline in cow herd numbers has also affected the overall cattle industry in Iowa as well. However, the continuing economic importance of the cow-calf enterprise in Iowa is demonstrated by the fact that there were 1.2 million beef cows in inventory on January 1, 1988 (Iowa Department of Agriculture, 1989). This is 4 percent of the U.S. total ranking Iowa 8th among all states in number of beef cows.

One problem confronting beef cow-calf producers is the relatively low profitability of their enterprise. Cost of production budgets complied by the USDA, ERS (1987) show that U.S. cow-calf operations, on average, experienced a loss in each year from 1985 to 1987 after deducting cash expenses and capital replacement costs. Those operations with 500 cows or more were the most profitable during the 1985-87 period showing positive returns to management and risk in 1987. Cow-calf operations with less than 100 cows, which is typical in Iowa, had the lowest returns of the three operation size groups. The main difference in profitability between these groups was their fixed cash expenses for interest and general farm overhead which were substantially higher for the small operations.

Regional differences in costs of production for cow-calf operations in 1987 were also found to be significant with the western U.S. having lower total cash expenses than the other producing regions. Operations in the north central region and in the southern states had higher capital replacement costs reflecting a larger per cow investment in equipment and facilities. One should also recognize that a higher proportion of the large cow-calf operations are located in the western U.S. than elsewhere. Iowa cow-calf producers may not be able to produce as cheaply as producers in other areas. For example, Iowa producers have higher fixed land costs than do their competitors in the Great Plains and the western U.S., who also benefit from low cost government range-land leasing arrangements. Cow-calf producers in the southern states have an advantage in being able to graze their cows year-round, thereby incurring minimal stored feed costs.

Traditionally, cow-calf producers have sold their calves at weaning or shortly thereafter as feeder calves. In an effort to increase profitability, many beef cow-calf producers have diversified their operations vertically by feeding their calves after weaning and selling them at heavier weights. Vertical integration, the combination and coordination of successive production and/or marketing stages within one firm, provides the producer with additional alternatives to the traditional marketing plan of selling weaned calves in the fall (Watt et al., 1987). A survey sample of 75 cow-calf producers in Iowa shows that 68 percent of producers precondition their calves, 38.7 percent of the producers do backgrounding and 37.3 percent finish their calves to slaughter (Strohbehn, 1988a). The term "retained ownership" is used to describe any production and marketing strategies where the calves are not sold at weaning and the producer retains ownership control beyond the weaning stage to sell the calves at a heavier weight. This can be accomplished either by placing the calves in a custom feedlot or by feeding the calves on the farm. Retained ownership expands the marketing opportunities for cow-calf producers making them less vulnerable to the cash feeder cattle price variability at weaning. The prices for feeder cattle are usually at their seasonal lows in the fall after weaning when a large proportion of weaned calves are sold to feedlot operations or backgrounders. The cash feeder cattle prices usually move higher through the winter reaching a seasonal high in April or May due to a high demand for cattle for grazing summer pasture (Strohbehn, 1988b). By retaining ownership the cow-calf producer can exploit this seasonal price pattern.

The existence of this seasonal price pattern suggests that there may be some inefficiency in the feeder cattle markets and its pricing structure. If the markets were totally efficient, then for a given investment the cow-calf producer's returns should equal that of the cattle feeder's. Several reasons for inefficiency in the feeder cattle market can be postulated.

The structure of the cattle industry is like a pyramid with large number of cow-calf producers selling calves to a smaller number of cattle feeders who in turn sell slaughter cattle to only a very small number of beef processors. This market structure tends to give cow-calf producers less "market power" as compared to cattle feeders and beef processors. Since most cow-calf producers in Iowa are small in size they may have even less bargaining power. Another factor is that the cow-calf producers in Iowa usually sell their calves at a nearby local auction barn which may have a limited number of buyers from a limited geographical area. Secondly, the high fixed investment in the cow herd creates an exit barrier which makes the producers slower in adjusting cow herd size during periods of unprofitability. Finally, many cow-calf producers have other motives besides profit maximization such as the psychological "utility" derived from the personal satisfaction of being a cow-calf producer, and so are less likely to liquidate the cow herd during periods of unprofitability (Musser et al., 1975).

Objectives of the Study

Previous normative studies in different regions have found that the beef cow-calf enterprise is not a optimal enterprise choice or that the optimal level of beef cows is lower than what is currently being produced when based on the profit maximizing criteria (Miller et al., 1978, and Musser et al., 1975). These discrepancies between the observed behavior of farmers and what is prescribed by profit maximizing normative models leads one to suspect that risk considerations should be included in the model, or that other goals and objectives besides profit maximization are involved.

Assuming that the beef cow-calf enterprise is already an integral part of the farming operation, the objective of this study is to evaluate the potential of alternative production and marketing strategies to improve the relative profitability of the cow-calf producer's operation. Some of the decision problems facing the cow-calf producer considering retained ownership are to decide what proportion of the calves should be retained if any, what and how long to feed those calves retained, and how to market these calves. If the producer does not have the necessary facilities to carry out these plans there is also a joint long-run investment decision to acquire the necessary facilities and equipment to feed cattle.

The main objective of this study is divided into three sub-objectives. The first is to list and describe the potential advantages and disadvantages of several retained ownership strategies. The second sub-objective is to evaluate the decision making process of the cow-calf producer in a dynamic or multiperiod framework at the enterprise level within the farming operation. The dynamic characteristics of the model will facilitate accounting for the investment decisions required to feed the calves on the farm.

The third sub-objective is to evaluate the impact of uncertain prices on the optimal decision strategy of the decision maker depending on the relative level of risk aversion exhibited by the decision maker. Stochastic prices and hence returns from the enterprises could affect the long-run decision strategy of a risk averse producer. The second and third sub-objectives require the construction of a multiperiod risk programming model which evaluates the impact of the joint investment and calf retention decisions over a seven year planning horizon. The model is representative of a farm in southern Iowa with an established cow-calf herd.

REVIEW OF MULTIPERIOD RISK MODELS

The appropriate method of incorporating risk considerations into a mathematical programming model has been the subject of much debate and poses a theoretical dilemma. Under the expected utility hypothesis the decision-maker's objective is to maximize utility. Utility is derived from present and prospective future consumption. The maximization of expected utility is different than simply maximizing profits over the decision-maker's time horizon. Utility maximization and maximizing profits are equivalent when the decision-maker's utility function is linear; the case when the decision-maker is defined as being risk neutral. If the decision-maker is risk neutral, then risk will not directly affect the decision-maker's choices of risky activities. However, if the decision-maker is risk averse, then risk considerations will affect the decision-maker's choices, and therefore, should be incorporated in the model. One approach is to select a "best" representation of the decision-maker's utility function and then maximize this function. The dilemma is that nonlinear functional forms of utility are not easily handled by traditional linear and quadratic programming techniques. One notable exception is the negative exponential utility function which exhibits constant absolute risk aversion for all levels of wealth. Selecting the appropriate form of the utility function is also a problem when the underlying risk preferences of the decision-maker are unknown.

Determining the decision-maker's preferences may require the use of various elicitation techniques, such as surveying preferences, which are difficult in practice to perform. It has been suggested that some decision-makers evaluate risky alternatives on the basis of a top priority survival goal and a profit maximizing goal. This has been termed the "safety-first" approach where the decision-maker seeks to attain a minimal acceptable income level with some degree of certainty as well as maximizing profits.

Alternative approaches which attempt to approximate expected utility maximization have been developed. One different and somewhat unique approach has been to measure risk as the negative deviations from a target return (Fishburn, 1977; Holthausen, 1981). Fishburn contends that decision makers very frequently associate risk with the failure to attain a target return. These "target" models also capture the concept of the safety-first approach. This type of risk measurement may be more appropriate than measures of the dispersion of a distribution such as the variance which equally weights both positive and negative deviations from the mean. If the variance is used as a proxy for risk in cases where price and return distributions are positively skewed, then the riskiness of these activities will be overestimated.

Multiperiod risk models can be divided into two classifications, nonsequential models and sequential models. According to McCarl (1986), nonsequential models represent "decide now, find out later with no intermediate information" type processes, whereas sequential models are an "alternative model form wherein decisions are made now, information is gained, then decisions may be altered, more information is gained, etc.". For example, a corn marketing problem can be modeled as a sequential process. The decision to store or sell corn is made virtually daily and as time passes information is obtained on market movements and developments which may cause the decision-maker to alter future decisions. In a nonsequential model all decisions for all future periods are determined simultaneously in the initial period with only all currently available information.

The selection of the appropriate model formulation depends on the decision process being modeled. Modigliani (1952) states that:

> Long-run plans are not necessarily made up in order to be carried out, but only to utilize all the available information in making the best possible decision for the present period. The relevant definition of the planning horizon is the time within which it is necessary to plan in order to make a decision for the first period.

As Hadley (1967) notes, one is usually interested in solving a sequential decision problem only for the purpose of making the initial decision. Therefore, a nonsequential decision-making process seems appropriate for modeling the facility investment decisions of the farm firm because this type of decision is made only once during the planning horizon and is difficult to change once made.

One of the earliest efforts to incorporate risk into a multiperiod linear programming model was Johnson et al. (1967). The authors formulated a farm growth model as a stochastic linear programming problem. In their model they apply the distribution method, which substitutes observed random variables into a deterministic model, to generate an approximate distribution function for the objective function of the stochastic linear programming problem. This approach generates sets of feasible farm plans, but does not determine the optimal farm plan for a given set of assumptions.

Barry and Willmann (1976) developed a multiperiod risk-programming model to evaluate forward contracting and other financial choices for farmers who are subject to market risks and external credit rationing. The problem is formulated as a multiperiod quadratic programming model with risk being evaluated according to a mean-variance criteria. Kaiser and Boehlje (1980) utilized a multiperiod MOTAD model to analyze the risk and return of a farm's investment, financing, production and marketing plans. Both of these models derive a solution for all periods simultaneously thereby generating a set of a priori growth plans for alternative combinations of risk and returns valued over the planning period. However, as McCarl (1980) comments the maximization of the expected utility of the summation of profits over time is not the same as maximizing the expected value of the summation of the utility from profits in each period, or in mathematical notation:

$$\text{Max } EU(\Sigma\ \pi_t) \neq \text{Max } E[\Sigma\ U(\pi_t)].$$

If the producer cares about period to period deviations in profits then the second expression is more appropriate.

Applications of multiperiod risk programming techniques to cow-calf or cattle production and marketing are relatively few. Gebremeskel and Shumway (1979) employ a two-year MOTAD model to determine forage species, fertilization rates, herd size, and the degree of on-farm integration for solution on an expected net return-mean absolute deviation (E-A) efficient set. Each year is divided into six bimonthly seasons to explicitly account for variations in forage quality. The LP risk model is used to estimate E-A efficient risk sets for long-run plans. A statistical decision theory approach that incorporates the LP risk model is then used to determine the optimal calf marketing strategies in the short-run.

More recently, Rawlins and Bernardo (1988) and Kolajo and Martin (1988) have extended previous work using multiperiod MOTAD models to model other regional cattle production and marketing problems.

A different approach was taken by Yager, Greer and Burt (1980) to determine the optimal policies for marketing cull beef cows. They properly formulated this problem as a sequential decision process rather than a once-and-for all decision. A stochastic dynamic programming formulation of the problem with a one-year planning horizon is used to determine an optimal decision rule for all states and stages of the process.

Another similar approach to the sequential decision-making problem is used by Schroeder and Featherstone (1988), who employ discrete stochastic programming methods to examine optimal calf retention and marketing strategies for cow-calf producers.

In conclusion, the proper formulation for a given problem depends on the decision-making processes involved and the objective of the study. For the purposes of this study, a nonsequential, multiperiod target MOTAD model is used to determine the optimal long-run plan for a cow-calf producer who must decide whether or not to invest in feedlot facilities in order to feed his/her own calves beyond weaning.

ANALYTICAL MODEL

The analytical decision model is an extension of the single-period target MOTAD model of Tauer (1983) and Watts et al. (1984) to the multiperiod case. The multiperiod linear programming model used here is similar to the multiperiod MOTAD model developed by Kaiser and Boehlje (1980), except that the target MOTAD formulation is used. The model also includes integer variables (0 or 1 values) to model first period investment decisions.

The general mathematical formulation of the proposed multiperiod target MOTAD model to be use in this study is shown below.

$$\text{Max } E(Z) = \Sigma_t{}^T\Sigma_{jn}c_{jt}x_{jt} + \Sigma_t{}^T\Sigma_k{}^p d_{kt}y_{kt} \qquad \begin{array}{l} j = 1,2,\ldots,n \\ k = 1,2,\ldots,p \\ t = 1,2,\ldots,T \end{array}$$

such that

$$\Sigma_j{}^n a_{ijt}x_{jt} + \Sigma_k{}^p g_{ikt}y_{kt} \leq b_{it} \qquad \text{for all } i = 1,2,\ldots,m \text{ and } t$$

$$\Sigma_j{}^n c_{rjt}x_{jt} + \Sigma_k{}^p d_{kt}y_{kt} + q_{rt} \geq T_t \qquad \text{for all } r = 1,2,\ldots,s \text{ and } t$$

$$\Sigma_r{}^s p_{rt}q_{rt} \leq \mathcal{L}_t$$

$$x_{jt} >= 0 \text{ , } q_{rt} >= 0 \text{ and } y_{kt} = [0,1]$$

where E(Z) is the expected income of the solution, c_{jt} is the expected return of activity j in period t, d_{kt} is the expected return of activity k in period t, y_{kt} is an activity level variable which can either be 0 or 1, T_t is the target level of income for period t, c_{rjt} is the return of j^{th} activity for the r^{th} observation in period t, p_{rt} is the probability that observation r will occur in period t, $\mathcal{L}_t$ is the absolute value of expected negative deviations from the target income level in period t. $\mathcal{L}$ is a constant which is parameterized from 0 to M with M being a large number to derive the E-A efficient set of target MOTAD solutions for each given level of target income.

The model is nonsequential in that the optimal level of each year's activities is determined simultaneously based on the information set the decision-maker has at the beginning of the first period. Therefore, the decision model does not account for forecast errors in the information set. The objective function maximizes the present value of income over a finite time horizon. The discounting of cash flows is explicitly accounted for by borrowing and savings activities. The decision-maker is assumed to be concerned with obtaining a reasonable level of income annually. Risk is measured annually as the negative deviation from a predetermined "target" level of income. Historical observations of activity returns are used to represent the riskiness of each activity. The weighted mean of the historical observations represents the expected return to the activity. In most cases, the historical observations are equally weighted in terms of their probability of occurrence. The risk for each year's plan within the multi-year model is evaluated as the weighted average of negative deviations of historically observed annual income from a target level of annual income.

EMPIRICAL MODEL

Background on Retained Ownership Strategies

Typically, cow herds in Iowa calve in the spring thereby producing calves which will be weaned in the fall at a weight of 400 to 650 pounds. Several other alternatives for Iowa beef cow-calf producers besides selling weaned calves in the fall can be examined. Production alternatives include custom feeding, backgrounding or wintering, wintering and pasturing the following year, and finishing for slaughter. Marketing alternatives include cash marketing of cattle at different weights up to and including slaughter, and the use of futures and options market hedging strategies.

Custom feeding refers to a contractual arrangement where the cattle are physically relocated to a second party's feedlot for growing and/or finishing. The daily responsibility of feeding and caring for the cattle is that of the second party who is paid for this service by the cattle owner. One restriction for the small cow-calf producer is that most custom feedlots require a minimum number of cattle to fill a lot, usually 50 to 100 head. The custom feeding alternative may require that the cow-calf producer buy additional calves to be fed or "pool" his calves with other producer's calves.

The term backgrounding (in this study) refers to a late fall and winter feeding program for weaned calves which prepares the cattle for placement on a finishing ration. Cattle in the backgrounding program are fed a high energy ration to obtain higher rates of gain as compared to the wintering program. The wintering program emphasizes low or slow rates gain that requires feeding a high roughage ration. The wintering program gives the producer the additional option of placing these cattle on pasture the following spring. Backgrounded calves are usually much heavier than the wintered calves in the spring so their capacity for growth on pasture is lower. Calves that are wintered and then placed on pasture in the spring and through the summer are called "long yearlings" after this period. The cow-calf producer has the option to sell his calves as feeders at any given weight, or to continue to feed the cattle to slaughter.

The Representative Farm Model

The multiperiod Target MOTAD model is constructed for a representative cow-calf producer in southern Iowa. In order to limit the model's size and complexity, a partial farm optimization approach is used to focus on the relationships and interactions between the cow-calf, cattle feeding and crop production enterprises. Therefore, all other livestock enterprises or off-farm employment activities are assumed fixed at their initial levels. The activities and constraints of the model are structured so that the production year begins on March 1. This "year" is subdivided into quarters which closely match the traditional seasons of the cow-calf production cycle: calving, summer grazing, weaning, and wintering periods for the cow herd.

The representative farm is assumed to have 75 acres of high quality crop land, 100 acres of medium quality crop land and 125 acres of poor quality land which can only be utilized as pasture[1]. Additional pasture land can be rented or medium quality land can also be used for pasture. Initially, the farm has a 50 head cow herd which utilizes the 125 acres of pasture. The farmer does not have adequate cattle feeding facilities, and presently sells all calves (except for replacement heifers) at weaning or shortly thereafter. The assumption is made that only one person provides labor directly for the farming operation. This person can provide up to 500 hours of labor per quarter of which 358, 361, 212 and 141 hours of labor in each respective quarter for a year beginning in March is allocated to the initial cow-calf and cropping enterprises. These labor commitments are based on the labor requirements for the assumed initial activity levels. Therefore, the remaining labor resources are assumed to be committed to and utilized by other livestock enterprises or off-farm employment which has an opportunity cost represented by the labor hiring activities included in the model.

The crop rotation alternatives initially selected are justified by previous results from an optimization model for similar representative farms (see Section I, p. 41). In addition to the other resource endowments, the farm is assumed to have a starting inventory of 5000 bushels of corn and 100 tons of hay.

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[1]Recent passage of Sod-Buster legislation is one justification of this land use restriction.

Cash flows from period to period are implicitly discounted by borrowing and saving activities. The model assumes quarterly interest rates of three and two percent respectively for the borrowing and saving. The maximum amount of capital that can be borrowed in any given period is $100,000.

Feedlot facilities

Budgets for low cost cattle feeding facilities with feedlot sizes of 50, 100, and 150 head of slaughter weight cattle were developed for the model and are included in Table A.15. The assumption is made that an existing farm building can be renovated or remodeled at half the cost of a new building shelter for use in the feedlot facilities. The cattle are to be fed cracked, ground or whole corn in wooden feed bunks and big round bales of hay in hay rings. The cattle feeding and handling equipment are assumed to have an estimated economic life of seven years, lot fencing has an economic life of 15 years, and the buildings and concrete have a 30 year life. The net present value of the salvage value of the feedlot facilities at the end of the model's time horizon is deducted from the initial cost in first period.

Management expertise

Above average management is assumed for the beef cow-calf enterprise and average management in all other enterprises. Furthermore, the cow-calf producer is assumed to have the required management expertise to feed cattle whatever feeding strategy is chosen. The backgrounding program in which the calves are placed on high concentrate rations typically requires a higher level of management than does a wintering program for calves. Most animal scientists agree that putting cattle on feed is more of an art than a science. In either case the producer is taking on more production risk, however, there is probably greater risk in the backgrounding program per se but the backgrounding activity has a shorter feeding period. The greater management expertise for the backgrounding enterprise is partially accounted for by the activities higher labor requirement.

Production activities

The crop rotations included in the model are a corn-soybean, corn-corn-oats-hay-hay and corn-oats-hay-hay rotations. The costs of crop production are based on information from Duffy (1987) who has compiled data from several university extension sources. The yields of the crop production activities are estimated for three productivity classes of land which are representative of productivity classes in southern Iowa.

The cow-calf maintenance activity budget represents the resources needed to annually maintain one cow unit which includes one cow, .04 bull and .2 bred replacement heifer. A calf crop of 95% of cows bred, 16% replacement rate, 1.5% death rate on replacement heifers and cows is assumed (Strohbehn, 1989). Therefore, a cow unit annually produces .31 head of heifer calf, .48 head of steer calf and .145 head of cull cow. The weaning weights for the heifers and steers are 500 and 550 pounds respectively, and the weight of a cull cow is 1150 pounds. It is assumed that the production system previously selected by the cow-calf producer for maintaining the cow herd and producing a weaned calf is optimal and separable from the other production and marketing decisions related to the retained ownership decisions.

The following retained ownership production activity options for both steers and heifers are considered:

1) a wintering program using high roughage rations (Table A.2).
2) a backgrounding activity which puts the calves on a high concentrate ration (Table A.3).
3) summer pasturing of wintered calves (Table A.4).
4) feedlot finishing of backgrounded calves (Table A.5).
5) feedlot finishing of summer pastured cattle (Table A.6).
6) custom feeding weaned calves to slaughter weight (Table A.7).
7) custom feeding wintered calves to slaughter weight (Table A.8).
8) custom feeding backgrounded calves to slaughter weight (Table A.9).
9) custom feeding cattle coming off summer pasture (Table A.10).

A flow chart showing the timing of and interrelationships between these on-farm production activities is presented in Figure 1.

All of the cattle feeding activities have fixed feed requirements and use simple corn and alfalfa-bromegrass hay or corn silage rations which were generated for specific rates of gain with the I.S.U. Extension Feedlot Performance Software (Wilson, Loy, and Rouse, 1986). The producer is given a choice between two different fixed feeding programs for the weaned calves retained on the farm. Unfortunately, LP models, in general, are not capable of determining both the optimal rate of gain and the least cost ration to produce that rate of gain because of the nonlinearities of the net energy system used to determine such rations. As the calf's weight increases over time the optimal rate of gain will change and so will the composition of the optimal ration thus making the problem dynamic as well. The rations used for the custom feeding, backgrounding, and finishing activities are near-optimal least cost per pound of gain rations established by comparisons to rations generated by a nonlinear optimization model (refer to Appendix C for a discussion of this model).

Weaned calves can follow two basic production paths which utilize the producer's own facilities and labor. Each production path gives the producer options to market feeder cattle at different weights and points in time prior to slaughter. In the wintering program, calves are fed a high roughage diet which results in lower rate of gain. The producer has the option then to sell these calves in the spring or to retain these cattle by putting them on pasture until the fall. When these cattle are taken off the pasture in the fall the producer again has the option to either sell or to feed these cattle to slaughter.

The calves in the backgrounding program are fed a high concentrate diet to achieve high rate of gains. The producer feeds these calves for 100 days. At that point the producer has the option to either sell the calves or to continue to feed the cattle to slaughter weight.

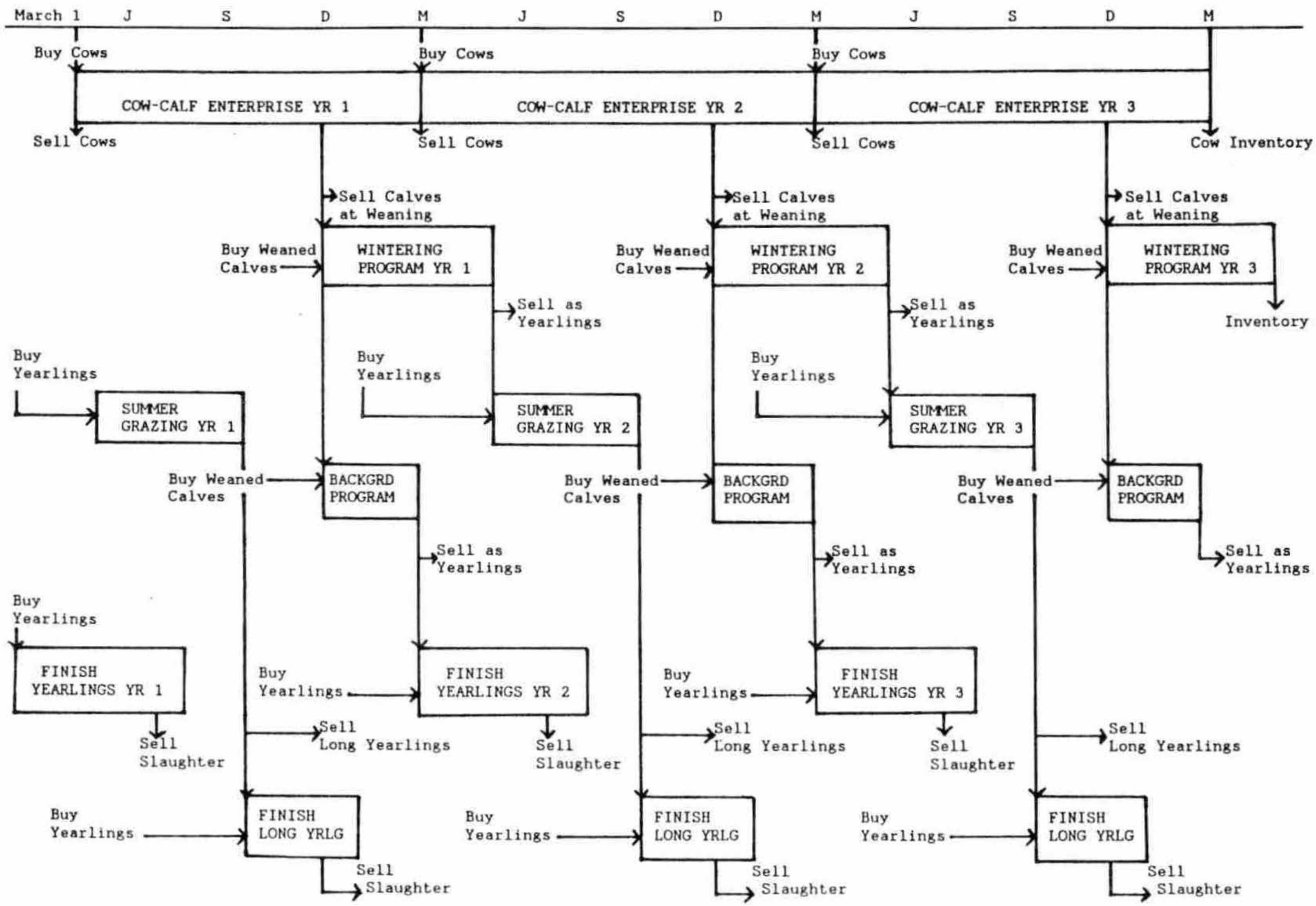

Figure 1. Flow chart showing the timing of and interrelationships between the on-farm production activities over a three year planning horizon

By making the decision to feed the calves the producer extends his/her marketing period and alternatives. Custom feeding represents another alternative, either by itself or in combination with the above strategies.

Custom feeding activities

Custom feeding activities to feed weaned calves to slaughter weight, wintered calves to slaughter weight and summer pastured cattle to slaughter weight are included in the model. The costs of custom feeding include yardage at 25 cents per head per day for weaned calves and 20 cents per head per day for older and heavier cattle. The higher yardage cost for weaned calves reflects the extra management required to handle these lighter weight calves and put them on feed as well as the preference of custom feedlots toward cattle weighing over 650 pounds. All feed costs, veterinary and medical expenses and death losses are paid or stood by the cattle owner. The feed costs are billed at the local elevator out-price (the model's buying price) and the price of corn silage is computed at 9 times the price of corn. A summary of survey information on custom cattle feeding is included in Appendix B.

Price Data and Marketing Activities

Monthly price data for Iowa crops and livestock were used to reflect seasonal price patterns. Price data for feeder cattle were divided by the animal's sex and weight class. Over time as the animal is fed and gains weight its weight class and therefore price per hundred-weight changes. Thus two price effects are being captured by the model. First, the seasonal trend or change in price levels, and secondly, the price change due to the animal's change in weight.

All production costs in the model are 1988 estimates and are assumed to be nonstochastic. The cost of the custom feeding activity is allowed to be stochastic to account for the stochastic variation in the price of corn and corn silage. All the monthly historical price series from 1982 to 1988 are detrended with a monthly implicit GNP price deflator which is estimated from quarterly GNP data. Therefore, all values used in the model are in terms of real 1988 dollars. The buying and selling activities reflect these stochastic prices and the associated marketing costs. The source for cash prices of corn, soybeans, oats and hay was the Iowa Department of Agriculture (1989). Their price series are adjusted for trend and reported in real 1988 dollars in Table A.11. Feeder cattle and slaughter cattle cash prices were taken from the USDA, Agricultural Marketing Service's Livestock Detailed Quotations 1982 through 1988 for the Iowa feeder cattle auction markets and the Iowa direct slaughter cattle markets respectively and are reported in real 1988 dollars in Table A.12.

The price differentials between the selling and buying price of cattle explicitly account for cash marketing and transportation costs that the seller or buyer must pay. Specifically, for feeder cattle sold in auction markets a 2 percent commission is paid by the seller to the auction market. Transportation or hauling costs of feeder cattle vary depending on the distance hauled and the weight or number of head loaded. All feeder cattle are assumed to be sold in local auction markets with an average distance of 50 miles at a total cost of \$0.28 per cwt. For slaughter cattle sold directly to the packing plant by the producer only transportation costs are incurred. A distance of 100 miles to a packing plant is assumed for slaughter cattle at a total cost of \$0.50 per cwt. The custom feeding activities include the transportation costs for shipping feeder cattle to the custom lot. A distance of 200 miles to the custom lot is assumed at a total cost of \$0.72 per cwt.

A consistent historical price series for bred cows was not available, and the correlation between the price of bred cows and slaughter cows on available data is relatively low. Therefore, it is assumed that the price of bred cows is the greater of \$88 plus the per head price of cull cows or \$580 per head. This was based on 1986 through 1988 data. The reasoning behind this assumption is that when the price of slaughter cows is relatively high it will drive the price of bred cows up as well, however when slaughter cow prices are relatively low the value of bred cows are independently determined. The prices of slaughter cows are more likely to be high during the expansionary phase of the cattle production cycle when bred cow prices are also higher.

Hedging activities

The units for the hedging activities are one contract, either a feeder cattle contract (44,000 lbs) or a live cattle contract (40,000 lbs) for slaughter weight steers or heifers. The contract months available for Feeder Cattle (FC) are January, March, April, May, August, September, October and November, and for Live Cattle (LC) are February, April, June, August, September[1], October and December. Presently, futures contracts can be made twelve months in advance, however futures trading in distant feeder cattle contracts may be thin or inactive. The prices used for the futures contract hedging activities were the weekly average of daily futures closing prices for the appropriate futures contract month for the week containing the selected date to place and lift the hedge (Chicago Mercantile Exchange, 1982-1988). If the selected date fell on a weekend then the following weekly average was used when placing the hedge and preceding weekly average was used when lifting the hedge. Broker's commissions and other transaction costs for one round turn transaction is about $68 per contract for both feeder cattle or live cattle futures contracts. Marketing constraints are used to limit the numbers of steers and heifers that can be hedged to less than or equal to those retained.

Each hedging activity represents a "routine production hedge" in that the cattle are hedged in the futures market at the beginning of the production period and the hedge is lifted at the end of the production period. Therefore, the hedging activity represent a 100 percent hedged position for a given number of cattle over a given

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[1]The September LC contract has just been recently added for 1989.

production period. In this "naive" pricing strategy the producer routinely hedges regardless of whether the price "locked in" by the hedge is above or below the producer's break-even price.

The futures market hedging activities are independent of the cash cattle marketings, and so there is no cash-futures price basis risk in this model. In theory, the expected value of a "routine" hedging activity should be equal to zero less the hedging transaction costs. The actual historical real returns to the hedging activities included in this model were all negative. Since the expected return to the included hedging activities is always negative a risk neutral producer will never hedge. However, a risk averse producer might hedge if the hedging activity stabilizes variations in annual income. A description and the historical returns of the six hedging activities in the model are included in Table A.13.

Put option hedges

Six "naive" at-the-money put option hedging strategies are also included in the model. The put option strategies were selected to closely match the futures contract hedges. The strike price selected for the put option contracts was either at-the-money or the strike price closest to being at-the-money for all hedges. The dates for placing and lifting the put option hedges were in some cases different from the futures contract hedging activities because of the unavailability of distant month put option contracts and the fact that put options for live cattle expire on the first Friday at least 3 business days prior to the contract month. In those cases where the corresponding live cattle futures contract hedge was not offset until the contract month, the put option contract hedge was assumed to be held until expiration. A more detailed discussion of agricultural commodity options is contained in Appendix D.

Put option contract premiums for both FC and LC are printed for only the three nearby contract months in the Wall Street Journal. More distant put option contract months are traded and usually six nearby contract months are available. However, a hedger may not be able to reasonably buy a put option because of lack of trading in a distant contract month. It is assumed as the options markets for LC and FC grow this will be less of a problem in the future.

Options trading of LC began on 10/30/84, and FC options began on 1/9/87. For the period 1982 through 1988 when actual options premiums were unavailable, the theoretical values for the put option premiums were calculated using Black's (1976) option pricing model with an assumed constant futures price volatility of 18% for both FC and LC. The selection of the level of volatility was based on the results from previous studies (Gordon, 1987; Firch and Dahlgran, 1987) and the implicit volatility computed from actual premium values observed in 1987 and 1988. The risk-free rate was assumed to be the average secondary market 3-month Treasury Bill yield for the month in which the transaction occurred (Board of Governors, 1989). The settlement price of the pre-selected hedge transaction date or the nearest trading day was used. The estimated historical returns of each put option hedging activity are included in Table A.14.

BUDGET ANALYSIS

Since the construction of the LP model requires the development of budgets for each activity, a preliminary analysis of these budgets can quite often give the researcher valuable information before the results of the LP model are generated. This information can be helpful in refining the LP model and heading off problems at an early stage. The budget analysis can also be useful in checking the LP model for errors by seeing if the LP solution makes sense.

The budgets for the different cattle feeding activities in Table 1 show a definite advantage for finishing yearling heifers over steers. Although heifers are less efficient in terms of overall feedlot performance, the greater price discounts for feeder heifers as compared to their feeder steer mates and the relatively small slaughter price discounts make finishing yearling heifers more profitable. Because of these price relationships, the heifer feeding activities also exhibit less price risk. Some producers feel, however, that there is greater production risk with heifers than steers, such as pregnancy or higher likelihood of poor performance. This may be just a management bias. On a dollars per head return basis, finishing "long" yearling heifers coming off of summer pasture shows the greatest return of all activities. The wintering feeding program for both steers and heifers show negative returns on average and only have positive returns in two years and one year respectively.

Table 1. Comparison of net returns from projected budgets of production and selling activities[a]

Budgeted Year	Cow-calf[b]
1988	120.40
1987	154.00
1986	74.96
1985	58.65
1984	27.95
1983	16.83
1982	59.97
Avg	73.25
Std Dev	45.31

					Custom Feeding	
Budgeted Year	Wintered Steer	Wintered Heifer	Bkgrd Steer	Bkgrd Heifer	Weaned Steer	Weaned Heifer
1988-82	-61.46	-92.70	-0.68	-36.22	92.86	111.93
1987-88	4.11	-20.25	72.72	41.68	37.81	56.69
1986-87	7.50	25.44	66.20	71.71	162.88	187.55
1985-86	-73.18	-67.98	-13.13	-3.14	27.89	34.60
1984-85	-40.16	-34.92	28.81	21.98	-81.85	-19.55
1983-84	-49.01	-56.87	32.90	25.98	61.20	70.87
1982-83	-18.63	-10.25	56.89	57.79	51.54	83.56
	-32.98	-36.79	34.82	25.68	50.33	75.09
	29.17	36.56	30.49	33.98	68.38	59.80

[a]The production year begins on March 1, production activities started in previous year are considered to have realized returns for that year.

[b]Capital costs for cow ownership are not included.

Table 1. Continued

Year	Summer Grazing Wintered Steer	Wintered Heifer	Finish Bkgrd Str	Finish Bkgrd Hfr	Finish LY Str	Finish LY Hfr	Custom Feeding Activities Wintered Steer	Wintered Heifer	Pastured Steer	Pastured Heifer
1988	13.64	12.01	-45.40	3.86	25.22	43.63	0.45	24.16	31.55	52.07
1987	84.06	77.54	87.41	105.34	-16.24	-23.10	103.99	93.39	-9.82	-13.39
1986	75.72	86.24	33.94	29.62	39.34	43.98	91.50	113.87	40.03	47.63
1985	-29.69	-1.45	-118.98	-50.48	113.58	101.05	-88.79	-47.17	112.96	102.98
1984	41.81	34.76	12.00	28.09	50.74	84.66	-6.57	35.30	51.47	87.32
1983	3.87	-40.38	-14.69	15.43	43.21	101.35	-41.23	-14.20	44.38	106.68
1982	54.69	53.64	79.45	134.01	-32.39	-1.26	32.74	61.19	-31.57	2.89
Avg	34.87	31.77	4.82	37.98	31.92	50.04	13.16	38.08	34.14	55.17
Std Dev	38.00	41.83	67.10	57.85	44.25	45.50	64.00	52.83	42.94	43.87

RESULTS OF THE MULTIPERIOD TARGET MOTAD MODEL

The Base Case

The results of the basic model as shown in Tables 2 and 3 for three sets of risk preferences indicate that cattle feeding is relatively more profitable than producing feeder calves and selling them at weaning. The selection of the optimal crop production activities (except pasture) is not affected by the producer's risk preferences, and appears to be separable from the selection of the livestock activity levels. The optimal solution for all risk preferences includes 75 acres of corn-soybean rotation and 100 acres of the CCOMM rotation.

Risk neutral preferences

The optimal solution for the risk neutral producer does not include the cow-calf enterprise. Part of the available pasture land is used for grazing yearling heifers. However, after the first year most of the land for pasture is unused. The profit maximizing solution in this case includes building the 150 head feedlot in which to background and finish purchased cattle. The custom feeding of heifer calves and yearling heifers coming off pasture is also included. The level of custom feeding is limited by the quarterly maximum borrowing constraints of the model.

Table 2. Level of investment and production activities for the base case

	Year 1	2	3	4	5	6	7
Risk Neutral Case							
Objective Function Value: $508,596							
Build Feedlot for 150 head[a]	1						
Backgrounding Steer Calves (hd)	48	48	48	48	48	57	200
Backgrounding Heifer Calves (hd	152	152	152	152	152	143	
Summer Grazing Yearling Hfrs (hd)	80	14	12	10	8	5	9
Feedlot Finishing of Yearling Backgrounded Heifers (hd)	118	150	150	150	150	150	142
Custom Feeding Heifer Calves (hd)	82	154	239	341	462	609	
Custom Feeding Steer Calves (hd)							893
Custom Feeding Yearling Heifers coming off summer pasture (hd)	183	254	330	420	528	657	811
Corn-Soybean Rotation (acres)	75	75	75	75	75	75	75
CCOMM Rotation (acres)	100	100	100	100	100	100	100
Maintaining Pasture (acres)	76	13	12	10	7	4	8
Moderate Risk Aversion							
Objective Function Value: $457,208							
Build Feedlot for 150 head	1						
Backgrounding Steer Calves (hd)						200	
Backgrounding Heifer Calves (hd)	63	93	130	196	200	200	
Summer Grazing Yearling Hfrs (hd)	79	132	132	132	132	132	132
Feedlot Finishing of Yearling Backgrounded Heifers (hd)	119	130	130	134	139	137	137
Feedlot Finishing of Long Yearling Heifers (hd)	103	80	53				
Custom Feeding Heifer Calves (hd)					76	176	

Custom Feeding Steer Calves (hd)							244
Custom Feeding Backgrounded							
Yearling Heifers (hd)					95	135	169
Custom Feeding Yearling Heifers							
coming off summer pasture (hd)	83	168	262	395	492	606	742
Corn-Soybean Rotation (acres)	75	75	75	75	75	75	75
CCOMM Rotation (acres)	100	100	100	100	100	100	100
Maintaining Pasture (acres)	75	125	125	125	125	125	125
Extreme Risk Aversion							
Objective Function Value: $391,425							
No Feedlot Facilities Build							
Cow-calf Enterprise (cow unit)	40	16	5				
Summer Grazing Yearling Hfrs (hd)	48	98	122	132	132	132	132
Custom Feeding Heifer Calves (hd)	5	1		5	13		
Custom Feeding Steer Calves (hd)							36
Custom Feeding Backgrounded							
Yearling Heifers (hd)	6	110	178	243	305	287	382
Custom Feeding Wintered							
Yearling Heifers (hd)	96	26	4				
Custom Feeding Yearling Heifers							
coming off summer pasture (hd)	121	235	307	381	460	552	658
Corn-Soybean Rotation (acres)	75	75	75	75	75	75	75
CCOMM Rotation (acres)	100	100	100	100	100	100	100
Maintaining Pasture (acres)	125	125	125	125	125	125	125

[a]Capacity for 150 head of slaughter weight cattle or 200 head of calves in the backgrounding or wintering program.

Table 3. Level of buying and selling activities associated with the base case

		Year						
		1	2	3	4	5	6	7
Risk Neutral Case								
Objective Function Value: $508,596								
Buy Steer Calves, Dec.	(hd)	48	48	48	48	48	57	48
Buy Heifer Calves, Dec.	(hd)	234	305	390	492	613	752	1093
Buy Wintered Heifers, Apr.	(hd)	80	14	12	10	8	5	9
Buy Backgrounded Hfrs, Mar.	(hd)	118						
Sell Backgrounded Strs, Mar.	(hd)		48	48	48	48	48	56
Buy Yearlings Heifers coming off Summer Pasture, Sept.	(hd)	105	240	318	410	521	653	802
Sell Slaughter Heifers, Jun.	(hd)	117	229	299	383	483	602	738
Sell Slaughter Heifers, Dec.	(hd)	182	251	326	416	523	651	803
Sell Corn, Dec.	(bu)							3618
Buy Corn, June-August	(bu)		1541	1541	1541	1541	1541	1456
Buy Corn, Dec-Feb.	(bu)	611	611	611	611	611	378	
Sell Soybeans, Nov.	(bu)	1312	1312	1312	1312	1312	1312	1312
Sell Oats, July	(bu)	1100	1100	1100	1100	1100	1100	1100
Sell Hay, large bales Aug.	(tons)	135	54	54	54	54	55	67
Moderate Risk Aversion								
Objective Function Value: $457,208								
Buy Steer Calves, Dec.	(hd)							444
Buy Heifer Calves, Dec.	(hd)	63	93	130	196	276	376	
Buy Wintered Heifers, Apr.	(hd)	78	132	132	132	132	132	132
Buy Backgrounded Hfrs, Mar.	(hd)	119	68	38	6	40	73	107
Buy Yearlings Heifers coming off Summer Pasture, Sept.	(hd)	108	118	186	265	362	477	612
Sell Slaughter Heifers, Jun.	(hd)	118	129	199	133	232	343	475
Sell Slaughter Heifers, Dec.	(hd)	184	245	312	391	487	600	734

Sell Corn, Dec.	(bu)	2263	1808					3618
Buy Corn, June-August	(bu)	18	1338	1338	253	1428	1402	1402
Buy Corn, Sept-Nov.	(bu)	2667	2080	1368				
Sell Soybeans, Nov.	(bu)	1312	1312	1312	1312	1312	1312	1312
Sell Oats, July	(bu)	1100	1100	1100	1100	1100	1100	1100
Sell Hay, large bales, Aug.	(tons)	168	84	66	58	57	57	67
Buy Hay, March-May	(tons)		12	12				
<u>Extreme Risk Aversion</u>								
Objective Function Value: $391,425								
Sell Steer Calves, Dec.	(hd)	19	8	2				
Sell Heifer Calves, Dec.	(hd)	12						
Sell Cull Cow, Feb.	(hd)	6	2	1				
Buy Steer Calves, Dec.	(hd)							36
Buy Heifer Calves, Dec.	(hd)					5	13	
Buy Wintered Heifers, Apr.	(hd)	144	124	126	132	132	132	132
Buy Backgrounded Hfrs, Mar.	(hd)	6	110	178	243	305	287	382
Buy Yearlings Heifers coming off Summer Pasture, Sept.	(hd)	74	138	188	252	331	422	528
Sell Slaughter Heifers, Jun.	(hd)	5	109	181	242	302	289	391
Sell Slaughter Heifers, Sept	(hd)	95	25	4				
Sell Slaughter Heifers, Dec.	(hd)	120	232	305	378	455	546	651
Buy Sept. FC Put Option					0.1			
Sell Corn, Dec.	(bu)	13253	8314	8332	8340	8340	8340	8340
Sell Soybeans, Nov.	(bu)	1312	1312	1312	1312	1312	1312	1312
Sell Oats, July	(bu)	1100	1100	1100	1100	1100	1100	1100
Sell Hay, large bales, Aug.	(tons)	126	104	121	126	126	126	126

Moderate risk aversion

At moderate levels of risk aversion the optimal plan also does not include the cow-calf enterprise. In this case, pasture land is fully utilized after the first year for grazing yearling heifers during the summer. The plan calls for building the 150 head capacity feedlot in which to background and finish heifers and to finish long yearling heifers coming off of pasture. The same custom feeding activities are selected as for the risk neutral case, but at lower activity levels. The income penalty for this case as compared to the risk neutral case is $51,387.

Extreme risk aversion

At extreme levels of risk aversion no feedlot facilities are built and the cow-calf enterprise enters the optimal plan for the first three years. The remaining available pasture land not used for cow-calf activity is utilized for grazing yearling heifers. The available labor resources are under-utilized in this case. The income penalty for this case as compared to the risk neutral case is $117,170. The plan calls for the custom feeding of weaned heifer calves, backgrounded heifer calves and long yearling heifers coming off of summer pasture. At this extreme level of risk aversion a small amount of hedging enters the optimal solution. This activity buys a September feeder cattle put option contract in April and represents a routine hedge of the yearling heifers grazing pasture.

Implications of Results from the Base Case

In general, the response to risk is expressed by some form of diversification. However, a risk neutral producer is more likely to build the on-farm feedlot facility than a farmer who is risk averse. In addition, the extremely risk averse producer will under-utilize labor resources rather than engage in a risky activity. The income penalties associated with risk averse behavior are quite large, and may offer explanation for the decision-makers choice of the beef cow-calf enterprise even though other activities may offer greater returns.

Sensitivity Analysis

A sensitivity analysis of the base model under different sets of assumptions was performed by changing the appropriate coefficients and re-optimizing the model to obtain a "new" solution. The changes in the optimal solution as compared to the base case are analyzed to obtain general trends and insights. The primary purpose of sensitivity analysis is to determine what set of circumstances include the beef cow-calf enterprise, and if so then what are the optimal retained ownership strategies in those situations. A comparison of the base case and selected sensitivity analysis cases for a producer with risk neutral preferences are contained in Table 5. Table 4 includes a partial list and definition of variables with their coded names as used in the model and is to serve as reference for variable names used in Table 5.

Table 4. List and definition of variables

Year 1 Investment and Production Activities:	
FACIL1	An activity to build a feedlot in the first period with a capacity to finish 50 head of cattle to slaughter weight or to background/winter 67 head of weaned calves.
FACIL2	An activity to build a feedlot in the first period with a capacity to finish 100 head of cattle to slaughter weight or to background/winter 133 head of weaned calves.
FACIL3	An activity to build a feedlot in the first period with a capacity to finish 150 head of cattle to slaughter weight or to background/winter 200 head of weaned calves.
COWCALF1	A cow-calf maintenance and production activity for year 1 that maintains one cow unit and produces a weaned calf.
CUSTMS14	An activity to custom feed a weaned steer calf to slaughter in the December to February quarter (4th quarter) of year one.
CUSTMH14	An activity to custom feed a weaned heifer calf to slaughter in the 4th quarter of year one.
CUSTBKS1	An activity to custom feed a backgrounded steer weighing 820 pounds to slaughter weight from March to July in year one.
CUSTBKH1	An activity to custom feed a backgrounded heifer weighing 735 pounds to slaughter weight from March to June in year one.
CUSTWS11	An activity to custom feed a wintered steer weighing 725 pounds to slaughter weight starting in the March-May quarter (1st quarter) of year one.
CUSTWH11	An activity to custom feed a wintered heifer weighing 655 pounds to slaughter weight starting in the 1st quarter of year one.
CUSTPS13	An activity to custom feed a yearling steer coming off of summer pasture weighing 925 pounds to slaughter weight starting on feed in Sept. (3rd quarter) of year one.
CUSTPH13	An activity to custom feed a yearling heifer coming off of summer pasture weighing 830 pounds to slaughter weight starting on feed in Sept. (3rd quarter) of year one.
BACKGRS1	A backgrounding activity that feeds a weaned steer calf to 820 lbs. using a high concentrate diet from December to February of year one.
BACKGRH1	A backgrounding activity that feeds a weaned heifer calf to 732 lbs. using a high concentrate diet from December to February of year one.

Table 4. Continued

SUMPASS1	An activity to graze a yearling steer weighing 725 lbs. on summer pasture from late April to mid-September.
SUMPASH1	An activity to graze a yearling heifer weighing 655 lbs. on summer pasture from late April to mid-September.
FEDYRLS1	An activity to feed a backgrounded yearling steer weighing 820 lbs. to slaughter weight from March to July.
FEDYRLH1	An activity to feed a backgrounded yearling heifer weighing 732 lbs. to slaughter weight from March to June.
FEEDLYS1	An activity to feed a "long" yearling steer coming off pasture weighing 925 lbs. to slaughter weight from September to December.
FEEDLYH1	An activity to feed a "long" yearling heifer coming off pasture weighing 830 lbs. to slaughter weight from September to December.
CSBG1	A corn-soybean crop rotation activity on high quality land in year one.
CCOMM1	A corn-corn-corn-oats-meadow-meadow crop rotation on medium quality land in year one. The meadow crop is alfalfa-bromegrass hay.
PASTURP1	A pasture growing and maintenance activity on poor quality land in year one.

Year 6 Production Activities:

The variables are named the same as for year one except that numerical index changes to represent year six. If two numbers are used in the variable name, the second number refers to the quarter in which the activity begins. The numerical quarter index always stays the same regardless of the production year index. The quarters are defined as March-May, June-August, September-November and December-February respectively as the 1st, 2nd, 3rd and 4th quarters of the production year.

Table 5. Comparison of the activity levels from the base case and selected sensitivity analysis cases

Risk Neutral Preferences

		Base Solution	A[a]	B[b]	C[c]	D[d]	E[e]	F[f]	G[g]	H[h]
			Sensitivity Cases							
Obj Fn Value		$508,596	$480,671	$354,242	$312,425	$433,531	$456,632	$342,997	$287,052	$308,550
Year 1 Investment and Production Activities:										
FACIL1										
FACIL2										
FACIL3		1	1	1	1	1	1	1		1
COWCALF1	(cow unit)		50	50	50	19	20	21	60	59
CUSTMS14	(hd)									
CUSTMH14	(hd)	82	56			109				
CUSTBKS1	(hd)									
CUSTBKH1	(hd)									
CUSTWS11	(hd)									
CUSTWH11	(hd)									
CUSTPS13	(hd)									
CUSTPH13	(hd)	183	122	112		158	158			
BACKGRS1	(hd)	48	74	184	184	71	48	10		182
BACKGRH1	(hd)	152	126	16	16	129	152	152		18
SUMPASS1	(hd)									
SUMPASH1	(hd)	80		1		52	8	7		
FEDYRLS1	(hd)									
FEDYRLH1	(hd)	118	123	118	118	118	150	150		
FEEDLYS1	(hd)									
FEEDLYH1	(hd)							29		
CSBG1	(acres)	75	75	75	75	75	75	75	75	75
CCOMM1	(acres)	100	100	100	100	100	100	100	100	100
PASTURP1	(acres)	76	100	101	100	88	48	48	121	119
Total Head Custom Fed		265	178	112		267	158			
Year 6 Production Activities:										
COWCALF6	(cow unit)		50	32	36			20	60	60
CUSTMS64	(hd)									
CUSTMH64	(hd)	609	573	315		332	468			
CUSTBKS6	(hd)									
CUSTBKH6	(hd)									
CUSTWS61	(hd)									
CUSTWH61	(hd)									
CUSTPS63	(hd)									
CUSTPH63	(hd)	657	564	465	55	592	612			
BACKGRS6	(hd)	57	108	173	187	68	48	10		181
BACKGRH6	(hd)	143	92	27	13	132	152	74		19
SUMPASS6	(hd)									
SUMPASH6	(hd)	5		65	56	132	108	89		
FEDYRLS6	(hd)									
FEDYRLH6	(hd)	150	91	58	11	130	150	150		
FEEDLYS6	(hd)									
FEEDLYH6	(hd)							87		
CSBG6	(acres)	75	75	75	75	75	75	75	75	75
CCOMM6	(acres)	100	100	100	100	100	100	100	100	100
PASTURP6	(acres)	4	100	125	100	125	102	125	121	121
Total Head Custom Fed		1266	1137	780	55	924	1080			

[a] Cow-calf activity forced into optimal solution at 50 cow units or greater.

[b] Assumes a 5% increase in prices for all classes of feeder cattle.

[c] Assumes a 5% decrease in prices for all slaughter cattle.

[d] Assumes a 10% increase in prices for corn, soybeans and oats.

[e] Assumes an increase in custom feeding yardage charges of $0.05 per head per day.

[f] Assumes that all custom feeding activities are not available or allowed in the optimal

[g] Assumes that all custom feeding activities are not allowed and that no on-farm feedlot facilities can be constructed.

[h] Assumes that all custom feeding activities are not allowed and that there is no feedlot finishing of yearling cattle.

Table 5. Continued

Risk Neutral Preferences

	Base Solution	Sensitivity Cases I[i]	J[j]	K[k]	L[l]	M[m]	N[n]	O[o]	P[p]
Obj Fn Value	$508,596	$294,932	$350,383	$333,741	$522,328	$291,070	$498,554	$499,772	$512,415
Year 1 Investment and Production Activities:									
FACIL1						1			
FACIL2									
FACIL3	1		1	1	1		1	1	1
COWCALF1 (cow unit)		60	50	50		62			2
CUSTMS14 (hd)		4							
CUSTMH14 (hd)	82	19	15		68		77	81	59
CUSTBKS1 (hd)									
CUSTBKH1 (hd)									
CUSTWS11 (hd)									
CUSTWH11 (hd)									
CUSTPS13 (hd)			24	89					
CUSTPH13 (hd)	183		15		185		179	184	159
BACKGRS1 (hd)	48		24	184	70	30	48	28	48
BACKGRH1 (hd)	152		146	16	130	19	152	152	152
SUMPASS1 (hd)									
SUMPASH1 (hd)	80				66		73	16	8
FEDYRLS1 (hd)				37					
FEDYRLH1 (hd	118		118		130	19	118	150	150
FEEDLYS1 (hd)									
FEEDLYH1 (hd)			22						
CSBG1 (acres)	75	75	75	75	75	75	75	75	7
CCOMM1 (acres)	100	100	100	100	100	100	100	100	100
PASTURP1 (acres)	76	121	99	100	125	125	70	15	49
Total Head Custom Fed	265	23	54	89	253		256	265	218
Year 6 Investment and Production Activities:									
COWCALF6 (cow units)		62	62	25		62			
CUSTMS64 (hd)		30							
CUSTMH64 (hd)	609	19	15	8	627		593	598	615
CUSTBKS6 (hd)									
CUSTBKH6 (hd)			19						
CUSTWS61 (hd)									
CUSTWH61 (hd)			19						
CUSTPS63 (hd)			30	406					
CUSTPH63 (hd)	657		19		673		645	651	661
BACKGRS6 (hd)	57			200	100	30	48		70
BACKGRH6 (hd)	143		171		100	19	152	146	130
SUMPASS6 (hd)				76					
SUMPASH6 (hd)	5		1		66		5	5	36
FEDYRLS6 (hd)				74					
FEDYRLH6 (hd)	150		150		128	19	150	150	150
FEEDLYS6 (hd)									
FEEDLYH6 (hd)			22						
CSBG6 (acres)	75	75	75	75	75	75	75	75	75
CCOMM6 (acres)	100	100	100	100	100	100	100	100	100
PASTURP6 (acres)	4	125	125	125	125	125	5	4	34
Total Head Custom Fed	1266	49	102	414	1300		1238	1249	1276

[i]Purchases of additional feeder cattle are not allowed in this case.

[j]Assumes that the level of the custom feeding activities can be no greater than the on-farm production of either steers or heifers respectively.

[k]Constrains the model so that no purchases feeder heifers can be made, therefore only allowing purchases of feeder steers.

[l]Assumes no expenditures on pasture growing and maintenance are made, therefore doubling the pasture acreage requirements for livestock.

[m]Model is restricted so that purchases of additional feeder cattle and the custom feeding of weaned calves are not permitted.

[n]Assumes that there is a 20% increase in the cost of building feedlot facilities.

[o]Assumes that no additional labor can be hired.

[p]Assumes that livestock labor requirements are decreased by 20%.

When the optimal solution of the model is forced to include 50 or more cows (Case A, Table 5), the loss in net present value of income over seven years for the risk neutral case is $27,925 which is significant but not devastating to the producer. Under these restrictions the optimal plan includes building the 150 head capacity feedlot in which to background home-grown and additional purchased calves. The steers are sold after backgrounding, the backgrounded heifers are retained to be finished for slaughter. Additional feeder heifers are purchased for the custom feeding of weaned heifer calves activity, and the custom feeding of yearling heifers coming off pasture activity. The 50 head cow herd only utilizes 100 acres of pasture leaving 25 acres of pasture land unused, since no other grazing activities are selected.

If the assumption is made that no custom feeding activities are available or that the producer is unwilling to custom feed (Case F), then the optimal plan includes 20 units of the cow-calf enterprise. In this situation the producer will choose to build the large sized feedlot (150 head) to background calves from the cow-calf enterprise and additional purchased heifers. These heifers continue to be fed to slaughter in the feedlot. In addition to the cow-calf activity, pasture is utilized for the grazing heifer activity. After summer grazing some of these long yearling heifers are finished out in the feedlot.

In case G of Table 5 where the model is restricted so that no custom feeding is allowed and no feedlot facilities can be built, the model selects the cow-calf enterprise (60 cows) over the yearling cattle grazing activities as the best use for the pasture land. In comparison to the base case there is a very large income penalty of $221,544 over the planning horizon under these restrictions.

A somewhat different situational restriction is shown in Case I, Table 5 in which purchases of additional feeder cattle are not allowed. This allows the producer to feed his own calves either at a custom feedlot or on the farm. In this situation the model will expand the cow herd to 60 head and custom feed all of the heifer calves and part of the steer calves.

Price Sensitivity

The sensitivity analysis shows that the optimal solution changes with small changes in relative prices. If the spread between feeder cattle and slaughter cattle prices narrow (as shown by Cases B and C in Table 5), then the relative profitability of the cow-calf enterprise improves enough to bring it into the optimal solution. The relative profitability of the custom feeding activities decrease causing them to drop out of the plan for the first year in Case C. Interestingly, even though the finishing activities are now less profitable than before the optimal plan still includes building the 150 head feedlot to background calves. A similar trend is found when the costs of custom feeding are increased effected by a five cents per head per day increase in yardage charges (Case E, Table 5).

Conversely, if the spread between feeder and slaughter cattle widens then a substantial increase in custom feeding is observed.

The optimal plan's sensitivity to hay prices was also analyzed. The cow-calf enterprise is optimal for the first year of the seven year long-run plan when the price of hay is decreased by 10 percent. Curiously, the cow-calf enterprise drops out of the optimal plan at moderate levels of risk aversion. However, at extreme levels of risk aversion the cow-calf enterprise is again included in the optimal plan at higher activity levels than for the extremely risk averse base case. A further decrease in the price of the hay to 15 percent below the base price results in an increase in the cow-calf activity for the risk neutral and extremely risk averse cases. In general, a decrease in the price of hay reduces the present value of the optimal plan because excess hay production is sold as a cash crop.

This analysis shows that the optimality of the beef cow-calf enterprise is sensitive to the price of hay. Hay prices are highly dependent on hay quality, and it is reasonable to assume that many producers feed lower quality hay to their beef cows than to their feedlot cattle thereby saving their higher quality hay, which receives a higher price, for cash sales. If this assumption is valid, then the model implicitly overcharges the beef cow-calf enterprise for the hay that it uses. Therefore, the beef cow's ability to utilize low quality forages, which is not completely accounted for in this model, may partially explain the selection of this enterprise in many farming operations.

The model is not as quite sensitive to changes in grain prices. An increase in feed grain prices (as shown by Case D) decreases the profitability of cattle feeding causing a reduction in custom feeding. However, the on-farm feeding activities remain relatively unchanged. With the increase in grain prices the beef cow-calf enterprise becomes optimal in the first year.

The model is not sensitive to increases in the cost of constructing feedlot facilities. A 20 percent increase in construction costs does not meaningfully change the optimal solution (Case N, Table 5).

Labor sensitivity

The effects of limiting labor resources were analyzed by assuming that no additional labor can be hired in the model (Case O, Table 5). This restriction does affect the optimal solution by reducing the backgrounding of steer calves and the grazing of yearling heifers, otherwise the activity levels remains relatively the same.

Changes in livestock labor requirements were also analyzed. A 20 percent decrease in the labor requirements for all livestock enterprises (Case P, Table 5) increases the competitiveness of the cow-calf enterprise as shown by the inclusion of 20 cows in the first year of the solution.

Farm size sensitivity

The sensitivity of the representative farm model to changes in the farm's land resource base was analyzed by making changes in the assumed land resource endowments. With risk neutral preferences, an increase in the endowment of pasture land does not affect the optimal solution because the present available pasture land is already under utilized. However, if the custom feeding of weaned calves is not available then this additional pasture will be utilized for the grazing heifer activity. As the level of risk aversion increases the additional pasture land is used to increase the number of yearling heifers grazed.

The elimination of the endowment of high quality land does not significantly affect optimal enterprise selection. The levels of custom feeding are reduced due to the reduction of capital which was generated by the crop production on the high quality land. Conversely, an increase in available high quality land increases the amount of available capital in the model which is used to increase the level of the custom feeding activities.

Pasture management

In another sensitivity case the assumption is made that the carrying capacity of the pasture is increased by 25 percent if the nitrogen fertilizer rates are increased by 20 lbs per acre thereby increasing forage production, and the pasture management technique is changed to a more intensive rotational grazing system. The resulting pasture requirements are 1.5 acres per cow-calf unit, .75 acres for a yearling steer and .71 acres for a yearling heifer as opposed to 2.0 acres per cow-calf unit, 1.0 acres per yearling steer and .95 acres per yearling heifer. The additional nitrogen fertilizer increases pasture production costs by $4.20 per acre. The results show that even in this situation grazing yearling heifers is preferred to the cow-calf enterprise in the risk neutral case and some of the available pasture land is unused in each year of the optimal plan. The results of the model in general imply that the use of pasture land is a marginal activity for the risk neutral producer. The risk averse producer tends to diversify by more fully utilizing pasture land and increasing the level of the yearling heifer grazing activity. Only in the the extremely risk averse case will the cow-calf enterprise begin to enter the optimal plan as seen in the base cases of the model.

Conversely, when no expenditures on pasture growing and maintenance are made thereby doubling the pasture acreage requirements for the livestock enterprises (as shown in case L of Table 5) the grazing of yearling heifers is still preferred to the cow-calf enterprise.

Implications from the Sensitivity Analysis

Several implications can be drawn from the results of the sensitivity analysis cases as compared to the base solution. Specifically, the results clearly show that the feeding and grazing of heifers is more profitable than for steers. The results from Case K (Table 5) show that if purchases of feeder heifers are not allowed there is income loss of $174,855 over the planning horizon. The result in this case is due both to the lower profitability of feeding steers and the higher capital investment required to purchase steers, which means fewer steers can be custom fed than heifers due to the maximum capital borrowing constraints of the model. The apparent reason for the higher profitability of heifer activities as compared to steers is the larger price discounts (from the steer price) for feeder heifers relative to the price discounts for slaughter heifers.

The cow-calf enterprise is also shown to be an optimal choice when purchases of feeder heifers are not allowed. This implies that producers who only consider feeding steers are more likely to include the cow-calf enterprise in their optimal plan.

The yearling heifer grazing activity as opposed to the cow-calf enterprise is selected as the optimal enterprise for utilizing pasture land in the base case. However, this choice is very dependent on and sensitive to the relative price relationships of the model. In this respect, the model's sensitivity to relative price relationships and more specifically, to feeder cattle and slaughter cattle price differentials points out the producer's need for good market forecasts on which to base production and marketing decisions.

Risk responses

The sensitivity analysis seems to confirm the implication that the response to risk is expressed by enterprise diversification, and that the selection of the cow-calf enterprise in some situations is done for that reason. One can not conclude that a risk averse producer will prefer the cow-calf enterprise more than a risk neutral producer in all situations because risk is only relevant to the combination of enterprises not each one alone.

The results of the base case and the sensitivity cases only included one of the routine hedging activities in the most extremely risk averse situation. Since all of the routine hedging activities included in the model have a negative expected returns, two different implications can be drawn from these results. First, even though the routine hedging activity has a negative expected return, it can be an optimal choice to reduce risk if the producer's level of risk aversion is high enough. Secondly, the fact that these routine hedging activities are infrequently selected implies that diversifying production provides sufficient risk protection.

The Model with Perfect Information

The argument has been made that the sequential time path ordering of events (i.e. the stochastic variables of the model) could greatly effect the optimal enterprise choices and level of activities. Furthermore, since producers do form expectations of future events and have some information base for doing so, they will alter their decisions through time. Therefore, in order to test the robustness of this nonsequential model, the assumption is made that the decision making period is the fourth quarter of 1981 and that the producer has perfect foresight or knowledge of the future. This requires that the model's structure be changed so that the returns to the activities in the model are time-ordered historically as observed from 1982 to 1988.

In addition, the hedging activities are set equal to zero. All other constraints remain the same. The model is then optimized as before.

In the perfect foresight case, the value of the objective function is $2,770,119 as compared to $508,596 in the risk neutral base case. The cow-calf enterprise does not enter the optimal solution in any year. The producer builds the large size feedlot to background 200 head of either heifers or steers depending on which is more profitable, and also finish out 150 head of heifers in certain years. In none of the years does the producer finish out the backgrounded steers. Yearling heifers to graze summer pasture are purchased in two of the seven years and because of the high level of this activity in 1986, 67 acres of medium quality land are used for pasture. In 1984, the producer finishes out 150 head of these heifers after the grazing period. The custom feeding of weaned heifer calves occurs in 3 of 7 years. The custom feeding of backgrounded heifers and wintered heifers occurs only in 1987 and 1986 respectively. Custom feeding of yearling heifers coming off pasture is done in the years 1983 through 1986. The producer always has 75 acres of corn-soybean rotation on the high quality crop land. On the medium quality land, the producer will have 100 acres of CCOMM in 3 of 7 years and will have 100 acres of COMM in 3 of 7 years. For 1986, the producer will only have 33 acres of COMM.

These results imply that the value of market information is quite high, and the producer should be willing to pay for market forecasts. The sensitivity of optimal enterprise choices to relative prices is also made apparent by these results. However, the model implicitly assumes that the producer can costlessly enter and exit any enterprise in any time period. If the model were to more realistically account for the adjustment costs incurred by switching from one enterprise to another, then somewhat different results may have been obtained.

SUMMARY AND CONCLUSIONS

In general, the results of this study show that "retained ownership" strategies offer great potential for increasing the profits of the cow-calf producer's operation. Custom feeding of weaned calves appears to be the best "retained ownership" option in terms of profitability. The disadvantage of custom feeding weaned calves is that additional calves must be purchased to meet the minimum lot size requirement of the custom feedlot. In many cases the number of calves required may make custom feeding inaccessible for small cow-calf producers. Even if custom feeding calves is a viable alternative, the results indicate that building feedlot facilities is advantageous and gives the producer more flexibility to diversify.

Placing weaned calves in the backgrounding program is definitely preferable to the wintering program in all situations analyzed. This also implies that the cow-calf producer should prefer feeding strategies with relatively high rates of gain. Feeding and grazing heifers is generally more profitable than for steers. The lone exception is a "terminal" backgrounding program. Therefore, cow-calf producers who are retaining and feeding their own calves should consider purchasing additional feeder heifers rather than steers to fill their feedlot or a custom feedlot pen.

The value of market information which can be provided by timely market forecasts is high. However, routine hedging strategies do not hold much potential for reducing the producer's price risk or enhancing a risk averse producer's returns. The potential for selective hedging strategies which incorporates information known at the time of the decision and/or market forecasts remains to be explored.

In conclusion, even with above average management the cow-calf enterprise still remains a marginal activity as compared with other cattle feeding enterprises. Therefore, the types of retained ownership strategies presented here can help the cow-calf producer diversify risks and improve profits.

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APPENDIX A

Introduction

The following tables represent the budgets and price data used in the construction of the multiperiod target MOTAD model. Tables A.1 through A.10 are the budgets for the livestock production activities included in the model. Tables A.11 and A.12 include the monthly prices for crops and livestock respectively for 1982 through 1988 reported as real prices in 1988 dollars. Data used to compute the returns for the futures and options hedging strategies are contained in Tables A.13 and A.14. The budgets developed for three sizes of low cost cattle feeding facilities are shown in Table A.15.

Table A.1. Budget and technical coefficients for cow-calf enterprise based on 1982 to 1988 averages

Unit of Activity:	Maintaining One Cow Unit[a]			
Average Calving Date:	April 15			
Average Weaning Age:	210 to 220 days			
Assumed Selling Date:	November 21			
Production:	hd	$/hd	Revenue	
Heifer Calf (hd) 500 lbs	0.31	329	101.99	
Steer Calf (hd) 550 lbs	0.48	404	193.92	
Cull Cow (hd) 1150 lbs	0.145	486	70.47	
		Total Revenue		$366.38
Labor:	hours	$/hr	Total $	
March-May	2.40	6.00	14.40	
June-August	1.05	6.00	6.30	
Sept-Nov	1.08	6.00	6.48	
Dec.-Feb	2.46	6.00	14.76	
				$41.94
Feed:	units	$/unit	Total $	
Corn (bu) Mar-May	0.50	2.86	1.43	
Corn (bu) Dec-Feb	1.50	2.65	3.98	
Hay (tons) March-May	0.88	61.53	54.15	
Hay (tons) Dec-Feb	1.12	61.99	69.43	
Pasture (ac)	2.00	21.00	42.00	
Corn Stalks (ac)	3.80	3.00	11.40	
				$180.95
Cash Costs:				
Supp & Min. (50 lbs.)	7.00			
Vet & Health	15.00			
Mach Fuel/repair	15.00			
Misc.	10.00			
Total Variable Costs:		47.00		
Cash Fixed Costs:				
Mach/Equip	15.00			
Bull depr	7.33			
Total Fixed Costs:		22.33		
Total Cash Costs[b]				$69.33
		Net Returns		$74.16

[a]One cow unit is defined as 1 cow, 0.2 bred heifer and 0.04 bull.

[b]The capital costs of cow ownership are not included.

Table A.1. Continued

Unit of Activity:	Maintaining One Cow Unit
Cash Costs Allocated by Quarters:	
March-May	38.00
June-August	8.00
September-November	15.00
December-February	8.00

Table A.2. Budget and technical coefficients for calves on a high roughage wintering program based on 1982 to 1988 averages

Unit of Activity:	One Steer			One Heifer	
Production:					
Starting Date:	Nov. 22			Nov. 22	
Ending Date:	April 16			April 19	
Starting Weight (lbs)	550			500	
Death Loss %	1			1	
Final Weight (lbs)	725			655	
Payweight (3% shrink)	703			635	
Days on Feed	147			150	
Average Daily Gain	1.19			1.03	
Selling Price $/cwt	74.19			67.89	
Selling Price $/head	521.74			431.34	
Selling Costs and Transp.	12.40			10.40	
Net Sales Price $/hd	509.34			420.94	
Labor:	$/hr	hours	Total $	hours	Total $
Sept-Nov	6.00	0.10	0.60	0.10	0.60
Dec.-Feb	6.00	0.60	3.60	0.60	3.60
March-May	6.00	0.40	2.40	0.40	2.40
Feed:	$/unit	units	Total $	units	Total $
Corn (bu) Dec-Feb	2.65	3.80	10.07	3.30	8.75
Corn (bu) Mar-May	2.86	2.10	6.01	1.90	5.43
Hay (tons) Dec-Feb	61.99	0.712	44.14	0.628	38.93
Hay (tons) Mar-May	61.53	0.378	23.26	0.367	22.58
Cash Costs:					
Supp & Min. 80 lbs	11.20		80 lbs	11.20	
Vet & Health	5.00			5.00	
Mach Fuel/repair	4.50			4.50	
Misc.	15.00			15.00	
Cash Fixed Costs:					
Mach/Equip	1.20			1.20	
Total Cash Costs	36.90			36.90	
Total Variable Costs		126.97			119.19
Purchase Cost $/hd		415.00			339.00
Net Returns		-32.63			-37.25

Table A.2. Continued

Unit of Activity:	One Steer	One Heifer
Cash Costs Allocated by Quarters:		
December-February	22.10	22.10
March-May	14.80	14.80

Table A.3. Budget and technical coefficients for calves on a high grain backgrounding program based on 1982 to 1988 averages

Unit of Activity:	One Steer			One Heifer	
Production:					
Starting Date:	Nov. 22			Nov. 22	
Ending Date:	March 1			March 1	
Starting Weight (lbs)	550			500	
Death Loss %	1			1	
Final Weight (lbs)	820			732	
Payweight (3% shrink)	795			710	
Days on Feed	100			100	
Average Daily Gain	2.70			2.32	
Selling Price $/cwt	73.38			68.21	
Selling Price $/head	583.37			484.29	
Selling Costs and Transp.	13.90			11.68	
Net Sales Price $/hd	569.47			472.61	
Labor:	$/hr	hours	Total $	hours	Total $
Sept-Nov	6.00	0.25	1.50	0.25	1.50
Dec.-Feb	6.00	0.75	4.50	0.75	4.50
Feed:	$/unit	units	Total $	units	Total $
Corn (bu) Dec-Feb	2.65	23.61	62.57	19.89	52.71
Hay (tons) Dec-Feb	61.99	0.275	17.05	0.26	16.06
Cash Costs:					
Supp & Min. 50 lbs	7.00		50 lbs	7.00	
Vet & Health	6.00			6.00	
Mach Fuel/repair	4.00			4.00	
Misc.	15.00			15.00	
Cash Fixed Costs:					
Mach/Equip	1.50			1.50	
Total Cash Costs	33.50			33.50	
Total Variable Costs		119.11			108.27
Purchase Cost $/hd		415.00			339.00
Net Returns		35.36			25.34
Cash Costs Allocated by Quarters:					
December-February		33.50			33.50

Table A.4. Budget and technical coefficients for grazing stocker cattle on summer pasture based on 1982 to 1988 averages

Unit of Activity:		One Steer		One Heifer	
Production:					
Starting Date:		April 20		April 20	
Ending Date:		Sept. 17		Sept. 17	
Starting Weight (lbs)		725		655	
Death Loss %		1.5		1.5	
Final Weight (lbs)		925		830	
Payweight (3% shrink)		897		805	
Days on Feed		150		150	
Average Daily Gain		1.33		1.17	
Selling Price $/cwt		69.28		65.20	
Selling Price $/head		621.61		524.93	
Selling Costs and Transp.		14.94		13.65	
Net Sales Price $/hd		606.67		511.28	
Labor:	$/hr	hours	Total $	hours	Total $
March-May	6.00	0.05	0.30	0.05	0.30
June-August	6.00	0.20	1.20	0.20	1.20
Sept-Nov	6.00	0.05	0.30	0.05	0.30
	$/ac	Acres	Total $	Acres	Total $
Pasture (ac):	21.00	1.00	21.00	0.95	19.95
Cash Costs:					
Supp & Min.	20 lbs	2.80	20 lbs	2.80	
Vet & Health		5.00		5.00	
Mach Fuel/repair		3.00		3.00	
Misc.		13.00		13.00	
Cash Fixed Costs:					
Mach/Equip		2.00		2.00	
Total Cash Costs		25.80		25.80	
Total Variable Costs			48.60		47.55
Purchase Cost $/hd			524.00		433.00
Net Returns			34.07		30.73
Cash Costs Allocated by Quarters:					
March-May		6.00		6.00	
June-August		19.80		19.80	

Table A.5. Budget and technical coefficients for feedlot finishing of backgrounded calves based on 1982 to 1988 averages

Unit of Activity:	One Steer			One Heifer	
Production:					
Starting Date:	March 1			March 1	
Ending Date:	July 12			June 26	
Starting Weight (lbs)	820			732	
Death Loss %	1			1	
Final Weight (lbs)	1180			1060	
Payweight (3% shrink)	1145			1028	
Days on Feed	134			118	
Average Daily Gain	2.69			2.78	
Selling Price $/cwt	69.35			68.96	
Selling Price $/head	794.06			708.91	
Selling Costs and Transp.	5.90			5.30	
Net Sales Price $/hd	788.16			703.61	
Labor:	$/hr	Hours	Total $	Hours	Total $
March-May	6.00	1.0	6.00	1.0	6.00
June-August	6.00	1.0	6.00	1.0	6.00
Feed:	$/unit	Units	Total $	Units	Total $
Corn (bu) Mar-May	2.86	32.35	92.52	31.95	91.38
Corn (bu) Jun-Aug	2.87	15.75	45.20	10.27	29.47
Hay (tons) Mar-May	61.53	0.095	5.85	0.094	5.78
Hay (tons) Jun-Aug	56.67	0.047	2.66	0.03	1.70
Cash Costs:					
Supp & Min. 34 lbs	4.76		30 lbs	4.20	
Vet & Health	6.00			6.00	
Mach Fuel/repair	7.00			7.00	
Misc	20.00			20.00	
Cash Fixed Costs:					
Mach/Equip	1.80			1.80	
Total Cash Costs	39.56			39.00	
Total Variable Costs		197.79			179.34
Purchase Cost $/hd		586.00			486.00
Net Returns		4.37			38.27
Cash Costs Allocated by Quarters:					
March-May	24.00			24.00	
June-August	15.56			15.00	

Table A.6. Budget and technical coefficients for feedlot finishing of summer pastured cattle based on 1982 to 1988 averages

Unit of Activity:	One Steer			One Heifer	
Production:					
Starting Date:	Sept. 18			Sept. 18	
Ending Date:	Dec. 27			Dec. 18	
Starting Weight (lbs)	925			830	
Death Loss %	1			1	
Final Weight (lbs)	1200			1085	
Payweight (3% shrink)	1164			1052	
Days on Feed	100			91	
Average Daily Gain	2.75			2.80	
Selling Price $/cwt	69.81			68.61	
Selling Price $/head	812.59			721.78	
Selling Costs and Transp.	6.00			5.43	
Net Sales Price $/hd	806.59			716.35	
Labor:	$/hr	Hours	Total $	Hours	Total $
Sept-Nov	6.00	1.0	6.00	1.0	6.00
Dec.-Feb	6.00	0.5	3.00	0.5	3.00
Feed:	$/unit	Units	Total $	Units	Total $
Corn (bu) Sept-Nov	2.59	29.16	75.52	25.9	67.08
Corn (bu) Dec	2.58	7.29	18.81	6.48	16.72
Hay (tons) Sept-Nov	59.26	0.158	9.36	0.164	9.72
Hay (tons) Dec	61.51	0.04	2.46	0.018	1.11
Cash Costs:					
Supp & Min. 25 lbs	3.50		23 lbs	3.22	
Vet & Health	5.00			5.00	
Mach Fuel/repair	4.50			4.50	
Misc.	20.00			20.00	
Cash Fixed Costs:					
Mach/Equip	1.80			1.80	
Total Cash Costs	34.80			34.52	
Total Variable Costs		149.96			138.15
Purchase Cost $/hd		623.96			527.13
Net Returns		32.67			51.08
Cash Costs Allocated by Quarters:					
September-November	24.80			24.52	
December-February	10.00			10.00	

Table A.7. Budget and technical coefficients for custom feeding weaned calves based on 1982 to 1988 averages

Unit of Activity:		One Steer		One Heifer	
Production:					
Starting Date:		Nov. 22		Nov. 22	
Ending Date:		July 13		June 28	
Starting Weight (lbs)		550		500	
Death Loss %		1.75		1.75	
Final Weight (lbs)		1180		1060	
Payweight (3% shrink)		1145		1028	
Days on Feed		235		220	
Average Daily Gain		2.68		2.55	
Selling Price $/cwt		69.35		68.96	
Selling Price $/head		794.06		708.91	
Selling Costs and Transp.		5.90		5.30	
Net Sales Price $/hd		788.16		703.61	
Labor:	$/Hr	Units	Total $	Units	Total $
Dec.-Feb	6.00	0.025	0.15	0.025	0.15
June-August	6.00	0.025	0.15	0.025	0.15
Feed Costs:	Price/uni	Units	Total $	Units	Total $
Corn (bu) Dec-Feb	2.70	16.46	44.44	13.95	37.67
Corn (bu) Mar-May	2.91	29.63	86.22	28.59	83.20
Corn (bu) Jun-Aug	2.92	14.32	41.81	9.44	27.56
Corn Silage (tons) Dec-Fe	27.00	1.037	28.00	0.981	26.49
Corn Silage (tons) Mar-Ma	29.10	0.491	14.29	0.475	13.82
Corn Silage (tons) Jun-Au	29.20	0.237	6.92	0.154	4.50
Supp & Min.	0.14	85	11.90	86	12.04
Receiving Hay (tons) Dec	60.00	0.012	0.72	0.012	0.72
Cash Costs:					
Transportation to lot			3.96		3.60
Yardage (days)	0.25	235	58.75	220	55.00
Vet & Health			10.00		10.00
Misc.			15.00		15.00
Total Variable Costs:			322.32		289.89
Purchase Cost $/hd			415.00		338.00
Net Returns			50.84		75.72
Cash Costs Allocated by Quarters:					
December-February			127.02		118.51
March-May			128.51		125.02
June-August			66.48		46.06

Table A.8. Budget and technical coefficients for custom feeding wintered calves based on 1982 to 1988 averages

Unit of Activity:		One Steer		One Heifer	
Production:					
Starting Date:		April 20		April 20	
Ending Date:		Sept. 24		Sept. 8	
Starting Weight (lbs)		725		655	
Death Loss %		1.5		1.5	
Final Weight (lbs)		1180		1060	
Payweight (3% shrink)		1145		1028	
Days on Feed		157		141	
Average Daily Gain		2.90		2.87	
Selling Price $/cwt	Sept.	67.32		65.99	
Selling Price $/head		770.81		678.38	
Selling Costs and Transp.		5.90		5.30	
Net Sales Price $/hd		764.91		673.08	
Labor:	$/Hr	Hours	Total $	Hours	Total $
March-May	6.00	0.025	0.15	0.025	0.15
June-August					
Sept-Nov	6.00	0.025	0.15	0.025	0.15
Feed Costs:	Price/uni	Units	Total $	Units	Total $
Corn (bu) Mar-May	2.91	10.34	30.09	9.23	26.86
Corn (bu) Jun-Aug	2.92	30.73	89.73	30.43	88.86
Corn (bu) Sept	2.70	6.2	16.74	1	2.70
Corn Silage (tons) Mar-Ma	29.10	0.535	15.57	0.467	13.59
Corn Silage (tons) Jun-Au	29.20	0.509	14.86	0.524	15.30
Corn Silage (tons) Sep	27.00	0.102	2.75	0.017	0.46
Supp & Min.	0.14	39	5.46	35	4.90
Cash Costs:					
Transportation to lot			5.22		4.72
Yardage (days)	0.2	157	31.40	141	28.20
Vet & Health			6.00		6.00
Misc.			10.00		10.00
Total Variable Costs:			228.13		201.88
Purchase Cost $/hd			524.00		433.00
Net Returns			12.79		38.20
Cash Costs Allocated by Quarters:					
March-May			76.54		70.27
June-August			127.99		127.56
September-November			23.29		3.76

Table A.9. Budget and technical coefficients for custom feeding backgrounded calves based on 1982 to 1988 averages

Unit of Activity:	One Steer			One Heifer	
Production:					
Starting Date:	March 1			March 1	
Ending Date:	July 13			June 27	
Starting Weight (lbs)	820			735	
Death Loss %	1			1	
Final Weight (lbs)	1180			1060	
Payweight (3% shrink)	1145			1028	
Days on Feed	135			119	
Average Daily Gain	2.67			2.73	
Selling Price $/cwt	69.35			68.96	
Selling Price $/head	794.06			708.91	
Selling Costs and Transp.	5.90			5.30	
Net Sales Price $/hd	788.16			703.61	
Labor:	$/hr	Hours	Total $	Hours	Total $
March-May	6.00	0.025	0.15	0.025	0.15
June-August	6.00	0.025	0.15	0.025	0.15
Cash Feed Costs:	$/unit	Units	Total $	Units	Total $
Corn (bu) Mar-May	2.91	29.63	86.22	28.59	83.20
Corn (bu) Jun-Aug	2.92	14.32	41.81	9.44	27.56
Corn Silage (tons) Mar-Ma	29.10	0.491	14.29	0.475	13.82
Corn Silage (tons) Jun-Au	29.20	0.237	6.92	0.154	4.50
Supp & Min.	0.14	6	0.84	10	1.40
Other Cash Costs:					
Transportation to lot			5.90		5.29
Yardage	0.2	135	27.00	119	23.80
Vet & Health			6.00		6.00
Misc.			10.00		10.00
Total Variable Costs:			199.29		175.87
Purchase Cost $/hd			585.57		486.27
Net Returns			3.30		41.47
Cash Costs Allocated by Quarters:					
March-May			136.26		132.71
June-August			62.73		42.86

Table A.10. Budget and technical coefficients for custom feeding cattle coming off summer pasture based on 1982 to 1988 averages

Unit of Activity:		One Steer		One Heifer	
Production:					
Starting Date:		Sept. 18		Sept. 18	
Ending Date:		Dec. 30		Dec. 20	
Starting Weight (lbs)		925		830	
Death Loss %		1		1	
Final Weight (lbs)		1200		1085	
Payweight (3% shrink)		1164		1052	
Days on Feed		103		93	
Average Daily Gain		2.67		2.74	
Selling Price $/cwt	Dec	69.81		68.62	
Selling Price $/head		812.59		721.88	
Selling Costs and Transp.		6.00		5.43	
Net Sales Price $/hd		806.59		716.45	
Labor:	$/Hr	Hours	Total $	Hours	Total $
Sept-Nov	6.00	0.025	0.15	0.025	0.15
Dec.-Feb	6.00	0.025	0.15	0.025	0.15
Feed Costs:	Price/uni	Units	Total $	Units	Total $
Corn (bu) Sept-Nov	2.64	22.14	58.45	21.84	57.66
Corn (bu) Dec	2.63	8.75	23.01	5.52	14.52
Corn Silage (tons) Sep-No	26.40	0.776	20.49	0.752	19.85
Corn Silage (tons) Dec	26.30	0.144	3.79	0.092	2.42
Supp & Min.	0.14	25	3.50	22.5	3.15
Cash Costs:					
Transportation to lot			6.66		5.98
Yardage (days)	0.2	103	20.60	93	18.60
Vet & Health			5.00		5.00
Misc.			7.00		7.00
Total Variable Costs:			148.80		134.47
Purchase Cost $/hd			624.00		527.00
Net Returns			33.79		54.98
Cash Costs Allocated by Quarters:					
September-November			113.00		110.54
December-February			35.50		23.64

Table A.11. Monthly Iowa cash crop prices

	Monthly Corn Price in Real 1988 dollars												
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1988	1.69	1.77	1.80	1.81	1.86	2.30	2.65	2.55	2.49	2.49	2.42	2.42	2.19
1987	1.42	1.36	1.41	1.49	1.60	1.65	1.55	1.39	1.39	1.49	1.57	1.64	1.50
1986	2.37	2.36	2.37	2.37	2.46	2.36	2.02	1.56	1.33	1.31	1.47	1.49	1.96
1985	2.80	2.79	2.85	2.88	2.85	2.80	2.75	2.55	2.55	2.29	2.30	2.33	2.65
1984	3.53	3.42	3.58	3.71	3.70	3.66	3.61	3.42	3.17	2.85	2.74	2.71	3.34
1983	2.67	2.92	3.12	3.41	3.52	3.48	3.54	3.81	3.70	3.54	3.58	3.54	3.40
1982	2.94	2.86	2.88	3.03	3.09	3.01	2.91	2.61	2.51	2.38	2.49	2.56	2.77
7 Year Avg	2.49	2.49	2.57	2.67	2.73	2.75	2.72	2.55	2.45	2.34	2.37	2.38	2.54

	Monthly Soybean Real Prices in 1988 dollars												
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1988	5.63	5.95	6.04	6.31	6.82	8.13	8.31	8.19	7.80	7.48	7.35	7.42	7.12
1987	4.80	4.78	4.82	4.95	5.28	5.49	5.31	5.08	5.01	5.07	5.35	5.58	5.13
1986	5.43	5.44	5.52	5.51	5.52	5.43	5.34	5.16	5.01	4.65	4.74	4.82	5.21
1985	6.36	6.19	6.38	6.33	6.15	6.07	5.84	5.47	5.33	5.22	5.23	5.34	5.82
1984	8.92	8.20	8.73	8.70	9.13	8.99	7.82	7.20	6.77	6.68	6.55	6.31	7.83
1983	6.40	6.56	6.74	7.10	7.03	6.83	7.26	8.57	9.51	9.10	9.05	8.76	7.74
1982	7.35	7.21	7.23	7.38	7.49	7.27	7.17	6.60	6.25	6.03	6.20	6.34	6.88
7 Year Avg	6.41	6.33	6.49	6.61	6.77	6.89	6.72	6.61	6.52	6.32	6.35	6.37	6.53

Table A.11. Continued

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
					Monthly Oats Real Prices in 1988 dollars								
1988	1.91	2.00	1.99	2.03	2.05	2.72	3.03	2.80	2.63	2.71	2.59	2.80	2.44
1987	1.62	1.75	1.70	1.62	1.79	1.66	1.44	1.56	1.67	1.74	1.77	1.90	1.69
1986	1.41	1.44	1.31	1.28	1.28	1.21	1.01	0.97	1.02	1.13	1.35	1.53	1.25
1985	2.00	2.00	1.97	1.99	1.82	1.75	1.45	1.33	1.26	1.21	1.23	1.39	1.62
1984	2.29	2.31	2.24	2.29	2.34	2.30	2.06	2.13	2.19	2.25	2.25	2.08	2.23
1983	1.98	1.98	1.95	2.17	2.04	1.89	1.86	1.86	2.09	2.17	2.15	2.31	2.04
1982	2.42	2.54	2.57	2.49	2.48	2.46	2.00	1.83	1.79	1.72	1.96	1.93	2.18
7 Year Avg	1.95	2.00	1.96	1.98	1.97	2.00	1.84	1.78	1.81	1.85	1.90	1.99	1.92

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
					Monthly Hay Real Prices in 1988 dollars								
1988	42.68	45.67	48.64	48.43	49.22	52.00	66.74	81.37	82.05	77.02	77.93	79.81	62.63
1987	42.90	44.87	42.66	42.54	42.41	44.36	40.13	40.03	40.95	40.87	41.81	44.78	42.36
1986	57.12	56.01	55.98	51.52	49.23	48.02	38.27	36.00	37.98	38.96	43.10	41.98	46.18
1985	63.14	60.79	57.36	52.80	50.46	48.14	45.85	47.94	48.92	49.87	49.74	51.76	52.23
1984	92.64	96.85	93.08	93.98	92.61	85.62	70.78	63.86	61.45	63.55	65.64	67.72	78.98
1983	64.08	65.10	66.11	64.76	66.94	64.42	63.07	62.89	78.96	83.29	80.67	82.66	70.24
1982	69.21	70.16	73.56	78.12	71.70	68.97	62.73	58.94	58.76	61.00	62.03	61.87	66.42
7 Year Avg	61.68	62.78	62.48	61.73	60.37	58.79	55.37	55.86	58.44	59.22	60.13	61.51	59.86

Table A.12. Cattle price series for selected months from 1982 to 1988 in real prices in 1988 dollars

Feeder Calves

YEAR	Nov 550 lb Steers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd	Nov 500 lb Heifers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd
1988	85.37	9.39	1.54	458.60	80.32	8.03	1.40	392.17
1987	80.81	8.89	1.54	434.03	78.16	7.82	1.40	381.56
1986	68.99	7.59	1.54	370.32	61.73	6.17	1.40	301.08
1985	70.28	7.73	1.54	377.27	60.89	6.09	1.40	296.94
1984	72.93	8.02	1.54	391.55	63.34	6.33	1.40	308.94
1983	72.20	7.94	1.54	387.62	61.77	6.18	1.40	301.27
1982	76.08	8.37	1.54	408.53	65.80	6.58	1.40	321.02
7 year	Avg 75.24	Avg 8.28		Avg 403.99	Avg 67.43	Avg 6.74		Avg 329.00

YEAR	Feb 750 lb Steers	March 750 lb Steers	F-M Avg 750 lb Steers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 795 lbs	F-M Avg 700 lbs Heifers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 710 lbs
1988	78.71	79.81	79.26	12.60	2.23	615.29	75.40	10.71	1.99	522.66
1987	69.06	69.31	69.19	11.00	2.23	536.79	67.07	9.52	1.99	464.67
1986	63.77	62.53	63.15	10.04	2.23	489.78	58.80	8.35	1.99	407.16
1985	73.45	70.53	71.99	11.45	2.23	558.65	65.68	9.33	1.99	455.03
1984	74.27	76.05	75.16	11.95	2.23	583.35	68.24	9.69	1.99	472.81
1983	77.38	77.94	77.66	12.35	2.23	602.82	72.47	10.29	1.99	502.24
1982	75.00	79.44	77.22	12.28	2.23	599.40	69.80	9.91	1.99	483.65
7 year	Avg 73.09	Avg 73.66	Avg 73.38	Avg 11.67		Avg 569.44	Avg 68.21	Avg 9.69		Avg 472.60

Table A.12. Continued

YEAR	April 700 lb Steers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 703 lbs	April 650 lb Heifers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 635 lbs
1988	80.83	11.36	1.97	554.90	75.98	9.65	1.78	471.05
1987	71.18	10.01	1.97	488.38	69.40	8.81	1.78	430.10
1986	63.03	8.86	1.97	432.27	56.24	7.14	1.78	348.20
1985	71.30	10.02	1.97	489.21	64.83	8.23	1.78	401.66
1984	75.03	10.55	1.97	514.91	65.75	8.35	1.78	407.38
1983	77.72	10.93	1.97	533.44	71.63	9.10	1.78	443.98
1982	80.26	11.28	1.97	550.94	71.40	9.07	1.78	442.54
7 year	Avg 74.19	Avg 10.43		Avg 509.15	Avg 67.89	Avg 8.62		Avg 420.70

YEAR	Sept 900 lb Steers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 897 lbs	Sept 750 lb Heifers	Mktg Costs $/hd	Transp Costs $/hd	Net $/hd 805 lbs
1988	72.21	12.95	2.51	632.21	69.21	11.14	2.25	543.74
1987	72.50	13.01	2.51	634.76	72.22	11.63	2.25	567.49
1986	65.04	11.67	2.51	569.19	62.73	10.10	2.25	492.62
1985	59.66	10.70	2.51	521.89	58.53	9.42	2.25	459.49
1984	70.55	12.66	2.51	617.62	63.86	10.28	2.25	501.54
1983	68.61	12.31	2.51	600.61	59.07	9.51	2.25	463.75
1982	76.42	13.71	2.51	669.27	70.80	11.40	2.25	556.29
7 year	Avg 69.28	Avg 12.43		Avg 606.51	Avg 65.20	Avg 10.50		Avg 512.13

Table A.12. Continued

YEAR	July Slaught Steers	Transp Costs $/hd	Net $/hd 1145 lbs	Jun-Jul Slaught Heifers	Transp Costs $/hd	Net $/hd 1028 lbs	Aug Slaught Steers	Transp Costs $/hd	Net $/hd 1145 lbs
1988	66.38	5.90	754.15	67.74	5.30	691.07	68.59	5.90	779.46
1987	68.59	5.90	779.46	69.76	5.30	711.83	67.12	5.90	762.62
1986	62.97	5.90	715.11	60.02	5.30	611.71	64.16	5.90	728.73
1985	58.08	5.90	659.12	59.16	5.30	602.86	56.98	5.90	646.52
1984	75.60	5.90	859.72	72.41	5.30	739.07	73.40	5.90	834.53
1983	73.93	5.90	840.60	72.85	5.30	743.60	71.98	5.90	818.27
1982	79.87	5.90	908.61	80.76	5.30	824.91	78.99	5.90	898.54
	Avg		Avg	Avg		Avg	Avg		Avg
7 year	69.35		788.11	68.96		703.58	68.75		781.24

YEAR	Aug Slaught Heifers	Transp Costs $/hd	Net $/hd 1028 lbs	Sept Slaught Steers	Transp Costs $/hd	Net $/hd 1145 lbs	Sept Slaught Heifers	Transp Costs $/hd	Net $/hd 1028 lbs
1988	67.70	5.30	690.66	68.62	5.90	779.80	67.89	5.30	692.61
1987	66.24	5.30	675.65	67.60	5.90	768.12	66.67	5.30	680.07
1986	63.26	5.30	645.01	64.08	5.90	727.82	63.27	5.30	645.12
1985	56.28	5.30	573.26	57.06	5.90	647.44	56.17	5.30	572.13
1984	71.42	5.30	728.90	70.71	5.90	803.73	68.97	5.30	703.71
1983	69.90	5.30	713.27	69.40	5.90	788.73	67.53	5.30	688.91
1982	76.36	5.30	779.68	73.78	5.90	838.88	71.44	5.30	729.10
	Avg		Avg	Avg		Avg	Avg		Avg
7 year	67.31		686.63	67.32		764.93	65.99		673.09

Table A.12. Continued

YEAR	Dec Slaught Steers	Transp Costs $/hd	Net $/hd 1164 lbs	Dec Slaught Heifers	Transp Costs $/hd	Net $/hd 1052 lbs	Dec Utility Cows	Cull Cows Transp Costs $/hd	Net $/hd 1150 lbs
1988	71.97	6.00	831.73	71.52	5.43	746.97	48.17	5.75	548.21
1987	65.56	6.00	757.12	64.52	5.43	673.33	49.60	5.75	564.65
1986	63.67	6.00	735.12	62.65	5.43	653.65	39.67	5.75	450.46
1985	69.12	6.00	798.56	68.03	5.43	710.25	38.11	5.75	432.52
1984	73.95	6.00	854.78	72.36	5.43	755.80	40.54	5.75	460.46
1983	74.34	6.00	859.32	72.96	5.43	762.11	40.76	5.75	462.99
1982	70.03	6.00	809.15	68.27	5.43	712.78	42.47	5.75	482.66
	Avg		Avg	Avg		Avg	Avg		Avg
7 year	69.81		806.54	68.62		716.41	42.76		485.99

Table A.13. Futures contract hedges (all values are real prices in 1988 dollars)

A) Hedge the production of weaned calves by selling November Feeder Cattle Futures (FC) on May 15 and then offsetting on November 10 by buying Nov. FC.

Year	NOV FC SELL 5-15	BUY 11-10	PROFIT $/CWT		Nov Cash 500 lb	Dev From Mean
1988	77.53	80.19	-2.66		87.20	10.86
1987	69.07	75.77	-6.69		82.50	6.16
1986	60.41	65.46	-5.05		69.75	-6.59
1985	74.39	69.92	4.47		71.17	-5.17
1984	73.42	74.20	-0.78		73.42	-2.92
1983	75.20	71.01	4.18		73.50	-2.84
1982	78.73	78.34	0.39		76.84	0.50
			AVG	STD	AVG	STD
			-0.88	3.97	76.34	5.89

B) Hedge the calves placed in the backgrounding program by selling March FC on December 1 of the preceding year and then offsetting on March 1 by buying March FC.

MARCH FC Year	SELL 12-1	BUY 3-1	PROFIT $/CWT		March Cash 750 lb	Dev From Mean
1988	73.75	82.25	-8.50		79.81	3.47
1987	63.84	71.48	-7.63		69.31	-7.03
1986	72.00	69.85	2.15		62.53	-13.81
1985	78.65	76.71	1.94		70.53	-5.81
1984	76.44	80.54	-4.10		76.05	-0.29
1983	77.70	85.59	-7.88		77.94	1.60
1982	79.71	81.47	-1.76		79.44	3.10
			AVG	STD	AVG	STD
			-3.68	4.24	73.66	5.95

Table A.13. Continued

C) Hedge the calves placed in the wintering program by selling April FC on December 1 of the preceding year and then offsetting on April 15 by buying April FC.

APRIL FC CONTRACT Year	SELL 12-1	BUY 4-10	PROFIT $/CWT		April Cash 700 lb	Dev From Mean
1988	72.92	80.35	-7.42		80.83	4.49
1987	62.95	71.87	-8.92		71.18	-5.16
1986	71.17	61.90	9.27		63.03	-13.31
1985	77.73	73.54	4.19		71.30	-5.04
1984	76.07	77.10	-1.03		75.03	-1.31
1983	77.46	82.63	-5.17		77.72	1.38
1982	79.50	82.39	-2.89		80.26	3.92
			AVG	STD	AVG	STD
			-1.71	6.02	74.19	5.81

D) Hedge the calves placed in the backgrounding program through the finishing phase for slaughter by selling the August Live Cattle Futures (LC) contract on December 1 of the preceding year and then offsetting on August 1 by buying the August LC.

Year	12/1/Y-1 Sell Aug-LC	Aug 1 Buy Aug-LC	Profit $/cwt		Aug Cash Price	Dev. From Mean
1988	61.24	66.28	-5.04		68.59	-0.16
1987	57.26	66.08	-8.82		67.12	-1.63
1986	64.23	62.17	2.06		64.16	-4.59
1985	71.25	57.13	14.12		56.98	-11.77
1984	72.57	72.59	-0.02		73.4	4.65
1983	69.40	73.71	-4.31		71.98	3.23
1982	75.00	76.26	-1.25		78.99	10.24
			Avg	Std	Avg	Std
			-0.47	6.82	68.75	6.54

Table A.13. Continued

E) Hedge the calves in the wintering program through the summer grazing phase by selling the September FC contract on December 1 of the preceding year and then offsetting on Sept. 15 by buying the Sept. FC.

SEPT F.C. CONTRACT Year	SELL 12-1	BUY 9-10	PROFIT $/CWT		Sept Cash 900 lb	Dev From Mean
1988	71.18	79.87	-8.70		72.21	-4.13
1987	64.54	81.24	-16.70		72.50	-3.84
1986	66.51	66.98	-0.46		65.04	-11.30
1985	74.17	63.36	10.81		59.66	-16.68
1984	73.69	72.96	0.73		70.55	-5.79
1983	75.33	67.15	8.18		68.61	-7.73
1982	77.12	82.41	-5.29		76.42	0.08
			AVG	STD	AVG	STD
			-1.63	8.85	69.28	5.11

F) Hedge the calves placed on summer pasture through the finishing phase by selling the February LC contract on April 15 and then offsetting by buying the Feb. LC on December 15.

Year	Apr 15 Sell Feb LC	Dec 15 Buy Feb LC	Profit $/cwt		Dec Cash Price	Dev. From Mean
1988	65.43	71.65	-6.23		71.97	2.16
1987	61.58	63.50	-1.92		65.56	-4.25
1986	57.70	59.20	-1.50		63.67	-6.14
1985	69.67	67.52	2.15		69.12	-0.69
1984	70.64	72.73	-2.10		73.95	4.14
1983	71.75	74.92	-3.17		74.34	4.53
1982	74.43	67.90	6.53		70.03	0.22
			Avg	Std	Avg	Std
			-0.89	3.80	69.81	3.75

Table A.14. Put option hedging strategies

OCTOBER FC PUT OPTION[a]

Year	5-15 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	Exp Date	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	166	78.00	78	6.26	3.725	10-27	81.45	7.35	0.00	-1648.49
1987	168	66.87	66	5.69	2.250	10-29	73.15	5.78	0.00	-1041.46
1986	169	56.50	56	6.14	2.425	10-30	61.15	5.19	0.00	-1153.65
1985	159	68.07	68	8.55	3.125	10-20	64.50	7.22	3.50	118.90
1984	159	64.57	64	9.88	2.650	10-20	66.50	9.33	0.00	-1329.93
1983	159	64.90	64	8.19	2.525	10-20	62.42	8.64	1.58	-540.99
1982	159	65.90	66	12.09	3.050	10-20	66.97	7.71	0.00	-1635.09
										Avg -1032.96

MARCH FC PUT OPTION

Year	12/1/Y-1 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	3/1 Days Exp	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	121	72.77	72	5.41	2.870	31	81.16	5.70	0.000	-1309.72
1987	115	61.36	62	6.00	2.775	26	68.70	5.54	0.020	-1300.34
1986	116	66.88	66	7.20	2.225	27	64.88	6.79	1.900	-213.94
1985	110	71.30	72	8.44	3.100	20	69.54	8.47	2.800	-205.60
1984	110	67.34	68	9.00	2.925	20	70.96	9.18	0.225	-1408.48
1983	110	65.82	66	7.94	2.675	20	72.50	8.35	0.025	-1419.43
1982	110	65.02	66	12.28	2.975	20	66.45	12.68	0.900	-1179.28
										Avg -1005.26

[a]The October option contract month was used instead of November because of better trading volume for the October contract in May.

Table A.14. Continued

APRIL FC PUT OPTION

Year	12/1/Y-1 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	4/10 Days Exp	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	149	72.28	72	5.41	3.250	19	79.64	5.91	0.000	-1472.72
1987	150	60.68	60	6.00	2.400	21	69.28	5.79	0.000	-1125.54
1986	144	66.30	66	7.20	2.800	15	57.67	5.84	8.330	2551.63
1985	141	70.66	70	8.44	2.725	11	66.86	7.86	3.200	169.90
1984	141	67.19	68	9.00	3.325	11	68.09	9.76	0.800	-1317.93
1983	141	65.79	66	7.94	3.000	11	70.18	8.21	0.025	-1584.20
1982	141	65.13	66	12.28	3.225	11	67.50	12.70	0.275	-1644.31
										Avg -631.88

SEPT FC PUT OPTION

Year	4/15 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	9/10 Days Exp	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	168	75.35	76	5.91	3.900	20	80.80	7.24	0.050	-1726.37
1987	163	66.70	66	5.79	2.300	15	79.36	6.36	0.000	-1065.97
1986	164	56.50	56	5.84	2.400	16	63.49	5.20	0.000	-1144.00
1985	159	67.95	68	7.86	3.175	11	58.28	7.23	9.720	3070.78
1984	159	65.55	66	9.76	3.250	11	65.30	10.38	1.200	-1067.77
1983	159	65.65	66	8.21	3.225	11	57.83	9.00	8.170	2466.60
1982	159	63.90	64	12.70	2.950	11	68.72	7.92	0.000	-1586.57
										Avg -150.47

Table A.14. Continued

AUGUST LC PUT OPTION

Year	12/1/Y-1 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	Exp Date	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	234	61.48	62	5.41	3.570	7-22	66.54	7.06	0.000	-1452.51
1987	235	55.65	56	6.00	2.650	7-24	64.22	5.87	0.000	-1120.65
1986	236	60.43	60	7.20	2.570	7-25	58.49	5.83	1.670	-442.66
1985	237	65.26	66	8.44	3.950	7-26	52.33	7.28	14.320	4468.49
1984	232	64.59	64	8.61	3.250	7-20	64.61	10.42	0.000	-1490.54
1983	233	59.42	60	7.94	3.575	7-22	63.11	9.21	0.000	-1700.17
1982	234	62.17	62	12.28	3.250	7-23	63.21	10.02	0.000	-1598.30
										Avg -476.62

FEB LC PUT OPTION

Year	4/15 Days Exp	Futures Price	Strike	Risk-Free Rate	Est. Premium	12/15 Days Exp	Futures Price	Risk-Free Rate	Est. Premium	Real $ Gain/ Loss
1988	280	66.40	66	5.91	3.825	36	72.72	8.07	0.075	-1538.01
1987	282	60.51	60	5.79	2.320	38	62.40	5.90	0.970	-609.54
1986	283	54.98	54	5.84	2.850	39	56.41	6.00	0.550	-1025.48
1985	284	64.60	64	7.86	3.600	40	62.61	7.20	3.500	-103.14
1984	285	63.63	64	9.76	3.950	41	65.52	8.27	0.900	-1414.31
1983	280	62.50	62	8.21	3.475	36	65.26	9.00	0.350	-1495.01
1982	281	62.56	62	12.70	3.350	37	57.07	7.94	5.000	725.25
										Avg -780.03

Table A.15. Low cost cattle feeding facilities investment renovating or remodeling existing farm buildings

Capacity for feeding 150 head of calves

Space Requirements for 150 head:					
	units	units/hd	total		
Building or Shelter	sq. ft.	20	3000		
Open Lot	sq. ft.	150	22500		
Dirt Mound	cu. yd.	2.2	330		
Concrete	cu. yd.	0.39	58.5		
Feeding Space on Bunks	ft.	2.17	325.00		
Estimated Costs of -					
Building Renovation/Remodeling and Repairs:					
1/2 of cost of new building shell ($3.00 per sq. ft.)					4500.00
Open Lot Fencing:					
Assume that one side of the building is used for lot fence					
Total Linear feet of lot fence required:			523		
Windbreak Fence			73.2	ft.	775.45
Cable Fence			449.4	ft.	741.48
Dirt Mound @ $1.50 per cu. yd.					495.00
Concrete (installed) @ 81 per cu. yd.					4738.50
Feeding Equipment:					
Feedbunks-wooden 16' 10 bunks @ $115 per bunk					1150.00
Hay Rings - 8' 6 rings @ $113 per ring					678.00
Cattle Waterer					400.00
Grinder-Mixer Used					2600.00
Handling Equipment:					
Squeeze chute with headgate (est)					1000.00
Corral Panels 10' 12 panels @ $61.75					741.00
Corral Gate 4' gate					57.00
Pipe Gates 2"x14' 3 gates @ 87.50					262.50
Feed Storage and Handling:					
Assume adequate on-farm storage or use grain bank at elevator					
Manure Handling Equipment:					
Assume present manure handling equipment adequate					
		TOTAL COSTS			18138.93

Table A.15. Continued

Capacity for feeding 100 head of calves					
Space Requirements for 100 head:					
	units	units/hd	total		
Building or Shelter	sq. ft.	20	2000		
Open Lot	sq. ft.	150	15000		
Dirt Mound	cu. yd.	2.2	220		
Concrete	cu. yd.	0.39	39		
Feeding Space on Bunks	ft.	2.17	216.67		
Estimated Costs of -					
Building Renovation/Remodeling and Repairs:					
1/2 of cost of new building shell ($3.00 per sq. ft.)					3000.00
Open Lot Fencing:					
Assume that one side of the building is used for lot fence					
Total Linear feet of lot fence required:			427		
Windbreak Fence			58.5	ft.	620.10
Cable Fence			368.2	ft.	607.45
Dirt Mound @ $1.50 per cu. yd.					330.00
Concrete (installed) @ 81 per cu. yd.					3159.00
Feeding Equipment:					
Feedbunks-wooden 16' 10 bunks @ $115 per bunk					805.00
Hay Rings - 8' 6 rings @ $113 per ring					452.00
Cattle Waterer					400.00
Grinder-Mixer Used					2600.00
Handling Equipment:					
Squeeze chute with headgate (est)					1000.00
Corral Panels 10' 12 panels @ $61.75					741.00
Corral Gate 4' gate					57.00
Pipe Gates 2"x14' 3 gates @ 87.50					262.50
Feed Storage and Handling:					
Assume adequate on-farm storage or use grain bank at elevator					
Manure Handling Equipment:					
Assume present manure handling equipment adequate					
		TOTAL COSTS			14034.05

Table A.15. Continued

Capacity for feeding 50 head of calves					
Space Requirements for 50 head:					
	units	units/hd	total		
Building or Shelter	sq. ft.	20	1000		
Open Lot	sq. ft.	150	7500		
Dirt Mound	cu. yd.	2.2	110		
Concrete	cu. yd.	0.39	19.5		
Feeding Space on Bunks	ft.	2.17	108.33		
Estimated Costs of -					
Building Renovation/Remodeling and Repairs:					
1/2 of cost of new building shell ($3.00 per sq. ft.)					1500.00
Open Lot Fencing:					
Assume that one side of the building is used for lot fence					
Total Linear feet of lot fence required:			302		
Windbreak Fence			42.2	ft.	447.32
Cable Fence			259.5	ft.	428.16
Dirt Mound @ $1.50 per cu. yd.					165.00
Concrete (installed) @ 81 per cu. yd.					1579.50
Feeding Equipment:					
Feedbunks-wooden 16' 10 bunks @ $115 per bunk					460.00
Hay Rings - 8' 6 rings @ $113 per ring					226.00
Cattle Waterer					400.00
Grinder-Mixer Used					2600.00
Handling Equipment:					
Squeeze chute with headgate (est)					1000.00
Corral Panels 10' 12 panels @ $61.75					741.00
Corral Gate 4' gate					57.00
Pipe Gates 2"x14' 3 gates @ 87.50					262.50
Feed Storage and Handling:					
Assume adequate on-farm storage or use grain bank at elevator					
Manure Handling Equipment:					
Assume present manure handling equipment adequate					
		TOTAL COSTS			9866.48

APPENDIX B

Survey Information on Custom Feeding Alternatives

Informal telephone interviews were conducted to obtained information on the costs and accessibility of custom cattle feeding for cow-calf producers. A southwest Iowa cattle feeder, who custom feeds some of his own cattle, and an employee of a northwest Iowa cooperative, which owns a custom feedlot and manages custom feedlots for others, were interviewed. The information obtained from these interviews was used to set realistic assumptions for the contractual arrangements and yardage costs for the custom feeding activities included in the model.

The Farmers Cooperative at Sioux Center, Iowa custom feeds cattle in its own totally sheltered confinement facilities and also manages outdoor feedlots of farmer-members who wish to custom feed cattle (Scott Joaning, Farmers Cooperative Society, Sioux Center, Iowa, telephone interview, 22 March 1989). The cattle owner stands all death losses and pays the feedlot yardage and the cost of all feeds plus a markup on the feed. The markup on corn is billed by using the local elevator's out-price for corn. For the total confinement unit the pen size is about 60 head and yardage is charged at 10.75 cents per head per day. This charge also includes veterinary services, but not the cost of medications. In addition, there is a $4.00 per ton feed delivery charge. For the outdoor feedlots pen sizes are usually larger. They may be as large as 100 to 300 head in some cases. The yardage is also higher from 12 to 14 cents per day, but there is no feed delivery charge. Most custom feedlots prefer starting cattle weights in the 650 to 900 pound range because of ration formulation, so finding a feedlot that will accept lighter weight feeder calves may be a problem. The relatively large pen size required for custom feeding creates another problem for the small cow-calf producer. He either must buy more feeder calves to place on feed or find other producer to which to pool their calves together to custom feed. The custom feedlot may allow the owner to feed steers and heifers together in one pen if the owner is willing to pay the cost of feeding MGA[1] to all cattle at a cost of 2.25 cents per head per day.

Information on custom feeding in Kansas was obtained from a telephone interview of Melvin Laughery (March, 1989), a southwest Iowa cattle feeder, who custom feeds. Custom feedlots in Kansas usually require pen sizes of 100 to 300 head of either steers or heifers. At Scott City, Kansas yardage is 23 cents per head per day for lots without a steam flaker for corn and 25 cents for lots with a steam flaker. The owner of the cattle pays the local elevator in-price for corn plus 25 cents per bushel for all corn fed. All other feed fed is billed at the feedlot's actual cost. The cattle owner pays all veterinary and medication costs plus $1 per head for each animal run through the chute.

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[1]MGA stands for melengestrol acetate, a feed additive which prevents heifers from exhibiting estrus. Estrous activity will decrease feedlot performance of the entire pen of cattle.

The feedlots do provide some marketing services. The cattle are sold at the feedlot to the packers at their liveweight at the lot less a 3 percent pencil shrink. The packers are then responsible for loading and transporting the cattle to the plant. The Kansas feedlots prefer to receive 650 to 850 pound cattle which they can get to full feed in 10 days.

At a representative southwest Iowa feedlot yardage was 20 cents per day and the cattle owner pays the local elevator in-price for corn plus 25 cents per bushel and all other feed costs.

APPENDIX C

A Model for Generating Optimal or Near-Optimal Rations for Beef Cattle

This appendix describes an extension of previous work done by Hertzler et al. (1988) utilizing nonlinear programming to determine optimal beef cattle diets[1] based on the Net Energy System. The model presented here extends their work by incorporating the Metabolizable Protein System from Iowa State University in place of the NRC crude protein requirements. The least cost per unit of gain (least-cost-gain) formulation of this model chooses feed ingredients and daily gain to minimize the daily feed costs per pound (or kilogram) of gain for cattle of a specific weight, frame-size and sex and is used to test and check the revised model. The model was solved using the GINO (General INteractive Optimizer) nonlinear programming software for micro-computers (Liebman et al., 1986).

Net energy system

The net energy system developed by Lofgreen and Garrett (1968) separately accounts for the energy required for body weight maintenance and the excess energy in the ration available for growth. The animal's maintenance requirements must first be met before any growth

[1]In this paper the terms "ration" or "diet" will be defined as a mixture of feedstuffs fed on a given day to cattle of a specific weight, frame-size and sex, whereas a "feeding program" is the set of rations fed over the entire feeding period.

can occur. The use of the net energy procedure is based on the fact that feeds given feedlot beef cattle have different fuel values depending on whether they are being used for the maintenance component (NE_m) or the production (gain) component (NE_g) of the total energy requirement. The NE_m requirement for beef cattle is a nonlinear function of the animal's weight. The predicted daily gain of the animal is a nonlinear function of the animal's weight and the NE_g available once the maintenance requirements have been met.

<u>Metabolizable protein system</u>

The metabolizable protein system (Burroughs et al., 1974) was designed to account for the rumen's ability to use nonprotein nitrogen (NPN) such as urea to produce microbial protein which can bypass the rumen to contribute to the total available Metabolizable Protein (MP). The Urea Fermentation Potential (UFP) of a feedstuff is a measurement of the amount of urea (or NPN) that can be transformed into rumen microbial protein when fed with a specific quantity of that feedstuff. The unit of measurement is grams of urea (44.8 percent nitrogen) or urea equivalent per pound of DM consumed. The UFP value of a feedstuff is a function of the amount of fermentable energy present in a feed as reflected by its TDN content and the amount of ammonia formed from feed protein degraded in the rumen. Therefore, a feedstuff can have either a positive or a negative UFP value.

A positive UFP value for a feed or ration is the estimated grams of urea, per pound of DM consumed, that if added to the ration can be transformed into microbial protein in the rumen. Feedstuffs which have a positive UFP have relatively high energy content. For example, corn has a UFP of +5.3 grams per pound of DM.

A negative UFP value indicates that there is excess ammonia formed from feed protein degraded by rumen fermentation which is incapable of being re-synthesized into microbial protein with the energy present in that feed. This is expressed as grams of urea equivalent per pound of DM. This excess ammonia (or NPN) from a feedstuff with a negative UFP value would become useful in rumen fermentation only if it can be combined or offset with feeds having equal or greater positive UFP values. An example of a feedstuff with a negative UFP is alfalfa-bromegrass hay which has a UFP of -10 grams of urea equivalent per pound of DM.

The mathematical model

The energy, calcium and phosphorus requirement constraints of the diet model all depend nonlinearly on the animal's weight and gain. In addition, the dry matter intake restriction of Owens and Gill (1982) is also nonlinearly dependent on weight. A set of linear constraints are incorporated into the model to account for MP content of each feed and its associated positive or negative UFP contribution to the ration. The diet model for a medium-frame steer which includes the MP and UFP constraints is shown below. The diet model can be modified for other types of animals by replacing the appropriate coefficients in the equations (NRC, 1984).

Minimize $(Y + \Sigma_i C_i F_i)/G$

subject to:

NE_g (Mcal/d): $\Sigma_i NE_{gi} F_i [1-(.04268W^{.75})/\Sigma_i NE_{mi} F_i]$

$\geq .013W^{.75}G^{1.097}$;

MP (g/d): $\Sigma_i MP_i F_i + 2.225UFPMP \geq \{.0526[24W^{.734}+(3527 - W)G]\}$;

UFP^+ (g/d): $\Sigma_i UFP^+{}_i F_i - UFPMP \geq 0$;

UFP^- (g/d): $\Sigma_i UFP^-{}_i F_i + UFPMP \leq 0$;

Ca (g/d): $\Sigma_i Ca_i F_i \geq [.007W+.071(121.6G$

$- 29.4(.013W^{.75}G^{1.097}))]/.5$;

P (g/d): $\Sigma_i P_i F_i \geq [.0127W+.039(121.6G$

$- 29.4(.013W^{.75}G^{1.097}))]/.85$;

DM (lbs/d): $\Sigma_i F_i \leq .0636W-.0000325W^2-11.21+.0039(SW-610)$ and

nonnegativity: $G \geq 0$; $F_i \geq 0$;

where Y is a daily yardage cost (\$/d), F_i is the i^{th} feedstuff (lbs/d of DM), C_i is the price of the i^{th} feed (\$/lbs of DM), G is the daily gain (lbs/d), W is the animal's current weight (lbs), SW is the starting weight at which the animal was placed on feed, NE_{mi} and NE_{gi} are the net energies for gain and maintenance of the i^{th} feed (Mcal/lb of DM), MP_i is the metabolizable protein content of the i^{th} feed (g/lb of DM), UFPMP is the grams of urea that can be converted into available MP, $UFP^+{}_i$ and $UFP^-{}_i$ are the urea fermentation potential of the i^{th} feed (g/lb of DM), and Ca_i and P_i are calcium and phosphorus of the i^{th} feed (g/lb of DM). The yardage costs included in the model can entail operating expenses for machinery, veterinary expenses, interest expenses and labor expenses of feeding cattle. The model's

UFP constraints control the contribution made by NPN to total MP in the ration to be the lesser of either the total positive UFP or the absolute value of the total negative UFP of the ration after multiplying times a conversion factor of 2.225 in each case.

An alternative to the least-cost-gain diet model is an optimal-return diet model which chooses feeds and daily gain to maximize returns above feed costs. The model above would then be changed to:

$$\text{Maximize } (PR)G - \Sigma_i C_i F_i$$

subject to the same constraints and where PR is the selling price of the animal ($/lb). Both the least-cost-gain diets and the optimal-return diets can be useful in planning a feeding program. Hertzler found that the optimal-return diets have slightly higher rates of gain than the least-cost-gain diets.

Another important finding made by Hertzler (1988) was that the dynamically optimal cattle feeding program found by rather complex free-time optimal control models or dynamic programming models can be closely approximated by a series of static optimal-return rations. Therefore by repetitively solving the optimal return model at increasing weights the complete set of these individual optimal daily rations will represent the optimal feeding program over time.

Results from the least-cost-gain ration program

Daily least-cost-gain rations were generated for increasing weights of cattle using the NCR's empty body weight gain (EBG) equations from net energy available for gain. The EBG equations were used instead of the live weight gain (LWG) equations because they give more realistic estimates of actual feedlot gain according to ISU Extension Livestock Specialists. Yardage costs were not included in the initial analysis and one should expect the inclusion of yardage costs to result in somewhat higher optimal rate of gains.

The feed ingredients available for this ration and their prices are listed in Table C.1.

Table C.1. Feed ingredient available for ration and prices

Feed Ingredient	%DM	Price/lb	Price/Unit
Corn grain	85	.046	2.576/bu.
Corn Silage	40	.013	26/ton
Oats	90	.055	1.76/bu.
Wheat	90	.06	3.60/bu.
Alfalfa-Br Hay	90	.025	50/ton
40% Supp.	90	.115	11.50/cwt
36% Supp.	90	.135	13.50/cwt
Limestone	98	.055	5.50/cwt
KCl	98	.125	12.50/cwt

In a feeding program for 500 to 650 lb steers at these relative prices corn silage is included in the ration. However, if corn silage is excluded from the program the optimal ration selected includes just corn grain and hay, and has a higher optimal rate of gain than the rate containing corn silage. Table C.2 shows how the two rations and rates of gain compare for a 510 pound steer.

Table C.2. Comparison of two rations and rates of gain for a 510 pound steer

Feed Ingredient	Ration w/ C.S.	Ration w/o C.S.
Corn grain	3.3 lbs	9.5 lbs
Corn Silage	15.6 lbs	
Alfalfa-Br Hay	3.7 lbs	4.8 lbs
Rate of Gain	1.64 lbs/day	1.98 lbs/day
Cost per	.2725	.2801
Cost per day	.4469	.5546

When the steer reaches 700 pounds corn silage drops out of the ration and only corn and hay are fed.

Price Sensitivity The sensitivity of the optimal ration to changes in relative prices of the feed ingredients was tested by raising and lowering the price of hay. The price of hay can be reduced to $0.02 per pound (from $50 to 40 per ton) with no change in the optimal ration for a 710 pound steer. A further reduction in the price of hay to $0.015 ($30 per ton) causes a slight change in the optimal ration decreasing the amount of corn by .64 lbs, increasing hay fed by .64 lbs and thereby reducing the optimal rate of gain.

The optimal ration for a 510 pound steer is sensitive to changes in the price of corn silage. An increase of the price of corn silage from $26 to $28 per ton causes corn silage to completely drop out of the optimal ration. However, a decrease in price of $4 to $22 per ton results in no change in the optimal level of corn silage fed.

<u>Optimal return per day rations</u>

Changing the objective function of the model to maximize the returns of feeding a steer given the value of each additional pound gained results in higher optimal rates of gain (and therefore a "hotter" ration) for the same weight cattle than for the least-cost-gain rations. The set of relative prices used causes the optimal-return model to always push for the maximum rate of gain. The initial rations generated were extreme in that they were almost exclusively made up of concentrates, therefore a minimum roughage constraint was added so that the ration contains a linear combination of at least 10 percent hay or 20 percent corn silage. The following example is again for a 510 pound medium frame steer calf with the minimum roughage constraint. Corn silage drops out of the optimal return ration once the steer reaches 590 pounds, then the ration consists of only corn grain, hay and protein supplement.

Table C.3. Optimal return ration for a 510 lb medium-frame steer[a]

Feed Ingredient	Ration w/ C.S.	Ration w/o C.S.
Corn grain	9.9 lbs	11.7 lbs
Corn Silage	6.2 lbs	
Alfalfa-Br Hay		1.4 lbs
36% Supp.	1.5 lbs	1.2 lbs
Rate of Gain	2.59 lbs/day	2.56 lbs/day
Return per day	1.114	1.103

[a]A selling price of $0.72 per lb is assumed.

The estimated feeding programs generated from both the optimal least-cost-gain diet and optimal-return models for a medium-frame steer were found to be consistent with the results from the Feedlot Projections Program for similar ration concentrate levels in terms of the proportions of the feed ingredients used. However, the optimal least-cost-gain diet have somewhat higher feed intake and predicted rates of gain. A comparison of the optimal least-cost-gain diet and the Feedlot Projections Program diet for a steer in the backgrounding program is shown in Table C.4.

Table C.4. Comparison of diets for a steer in the backgrounding program.

	Optimal LCG	Projections
Corn (lbs)	1,504	1,322
Hay (lbs)	418	550
ADG (lbs/day)	2.80	2.70

APPENDIX D

Agricultural Commodity Options

Agricultural commodity option contracts are based on existing commodity futures contracts. A commodity option contract gives the buyer the right to take position in the underlying futures market at a specified price but the buyer has no obligation to exercise this right. The buyer of the commodity option may exercise this option at any time during the life of the contract but the seller cannot force him to do so. The seller of a commodity option is paid a premium for taking on the obligation to provide the buyer with either a long or short position in the futures market at pre-specified price. This price is called the *strike price* of the option contract. There are two types of option contracts depending on what right the buyer wishes to buy. If the buyer buys the *right to sell* at the strike price this is called a *put option*. In this case, if the option is exercised, the option seller must provide the buyer with a short position in the underlying futures contract at the strike price specified by the contract.

The *right to buy* at the strike price is called a *call option*, and the buyer has purchased the right to buy a commodity futures contract from the seller of the call at a specified price. So there are separate but related markets for put options and call options.

The economic life of both options and futures contracts are limited by their respective contract expiration dates. In the case of feeder cattle both the futures and options for a given month expire on the same day. However, for Live Cattle contracts the options expire in the month prior to the delivery month of the futures contract. The expiration dates limit the time period in which these instruments have economic value.

The market value of an option is determined by its *intrinsic value* from the return one would receive if it were exercised immediately and its *time value* from the chance that it will gain value between now and the expiration date. Therefore, the market value of an option will always be at least as much as its intrinsic value and usually more depending on the time value of the option. We would expect the owners of an option who could profit if they exercised that option to instead sell the option to someone else to profit from the sale and thereby capture additional gains from the option's time value.

If an option's strike price is such that an immediate exercise of the option would give positive returns, it is said to be *in-the-money*. Similarly, an *out-of-the-money* option is an option with a strike price such that an immediate exercise of the option would give a negative return. An *at-the-money* option has strike price equal to (or nearly equal to) the current futures market price, so that there would be no gain or loss upon exercise.

Hedging with options has some advantages over futures contracts. In options trading the buyer is assured that the initial cost of the option is the limit of the buyer's cost. The buyer can lose no more than the amount paid to purchase the option. In a futures hedge there is no initial cost but the hedger must put up "good faith" money in a margin account. However, there is no limit to the losses that one can accumulate in the futures position which should be offset by gains in the cash market. By purchasing a put option the hedger can guarantee a minimum price without limiting gains from upward price improvements, whereas the futures hedge establishes a given price (depending on basis movements) at the time of the hedge.

GENERAL SUMMARY

In Section I, an analysis of 1982 county level census data of found that beef cow, horse and sheep enterprises were positively related or compatible with part-time farming. Part-time farming was negatively correlated with dairy and sow farrowing enterprises. The relationships between part-time farming, and cattle and hog feeding enterprise were ambiguous. The information from the positive analysis was then used to help construct a normative model.

A normative decision model of a representative farm in south central Iowa was then used to determine optimal farm enterprise combinations that are compatible with off-farm employment (i.e., part-time farming). As compared to the rest of the state of Iowa, south central Iowa has lower quality land resources and a higher prevalence of beef cow-calf enterprises. The results from the normative model show that hog feeding and cattle feeding enterprise are optimal enterprise choices when off-farm jobs for the farm family are selected. As the level of off-farm employment decreases the sow farrowing enterprise enters the optimal enterprise mix. The sow farrowing enterprise is also selected when risk aversion is a consideration of the farm family. A sensitivity analysis of the model's results showed that the inclusion of the beef cow-calf enterprise in the optimal farm plan is unlikely in most part-time farming situations. The cow-calf enterprise is more likely to included in the optimal plans of full-time farmers.

Section II presents a multiperiod risk programming model which is used to analyze alternative production and marketing strategies for southern Iowa beef cow-calf producers. The results from the model show that beef cow-calf producers can benefit by retaining calves in both custom feeding activities and on-farm cattle feeding activities. Therefore, it may be prudent and wise for cow-calf producer to invest in adequate feedlot facilities.

Relative price relationships play a critical role in determining the optimal enterprise choices, and given the historical price relationship over the past seven years the cow-calf enterprise is not as profitable as other cattle feeding and grazing activities. Routine futures and options market hedging strategies do not provide an optimal means to reduce the producer's price risk. Instead, enterprise diversification is used to reduced the producer's risk. However, selective hedging strategies were not examined and may hold greater potential for reducing risk exposure and increasing returns.

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